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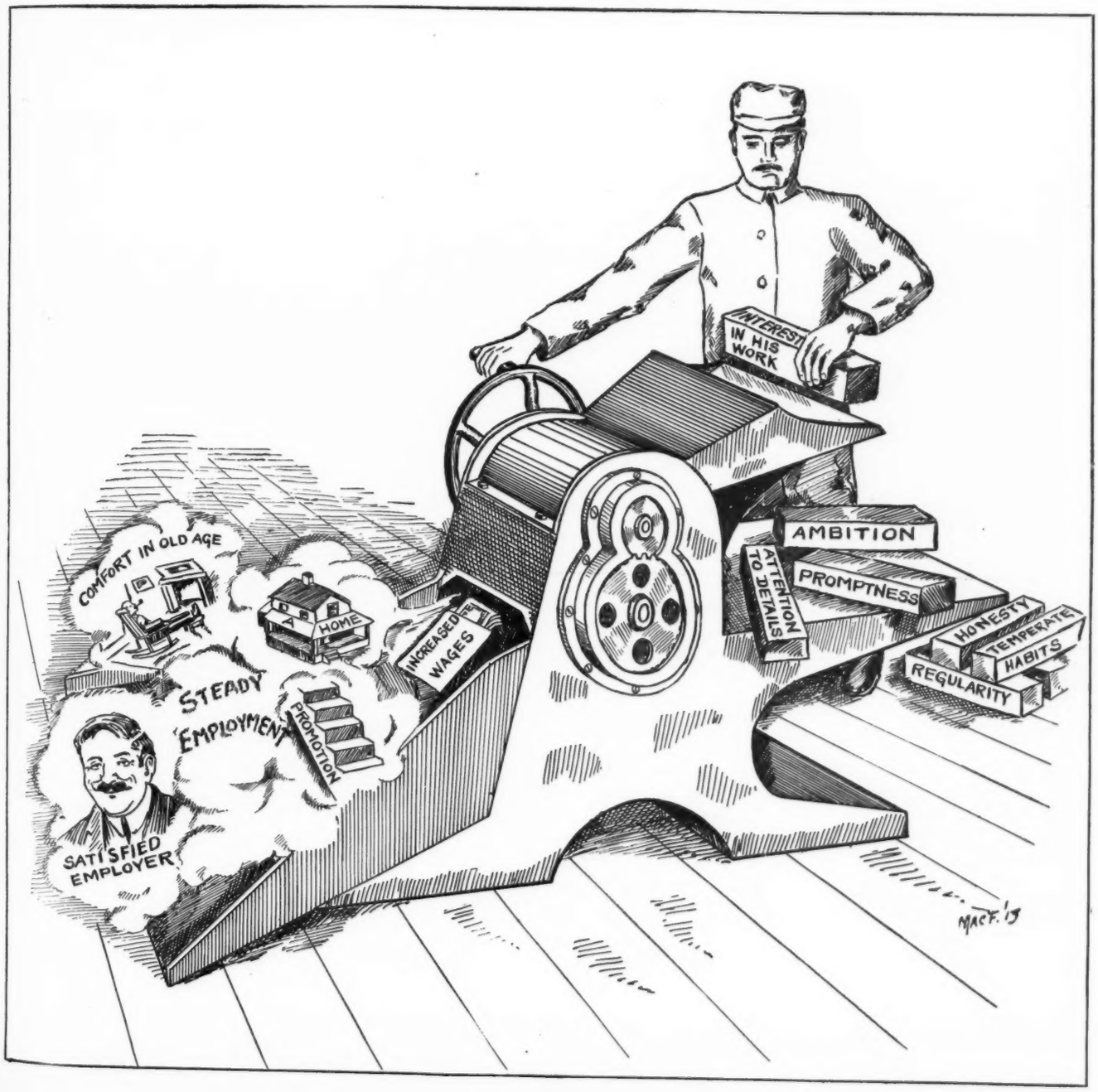
The Mill of Life



WHAT YOU GET OUT DEPENDS ON WHAT YOU PUT IN

Plant of Worcester Salt Co.

By Charles H. Bromley

SYNOPSIS—Fresh water is pumped to wells leading to salt cavities in the earth, the water dissolves the salt and the brine is raised to the surface by air lifts. Bituminous slack is burned in the boilers, the coal being fed to the stokers by gravity from a suspended bunker 300 ft. long. Much exhaust and low-pressure steam is used for evaporating brine and drying salt.

The power-plant man who has never seen a salt works in operation will find much to interest him in the plant of the Worcester Salt Co., at Silver Springs, N. Y.

In some salt regions, the product is mined, blasted out like rock in a quarry, but at Silver Springs it is dissolved by fresh water pumped into salt cavities in the earth. The aim is to obtain a brine of maximum saturation before raising it to the surface by air-water lifts. Fig. 1 shows two views of the works, the condenser water-cooling pond and the salt-well towers. Nature has eliminated the necessity of pumping the brine from the surface of the wells to the settlers seen at the edge of the pond in the top picture. The wells are on different levels and the brine flows by gravity in troughs leading to the settlers.

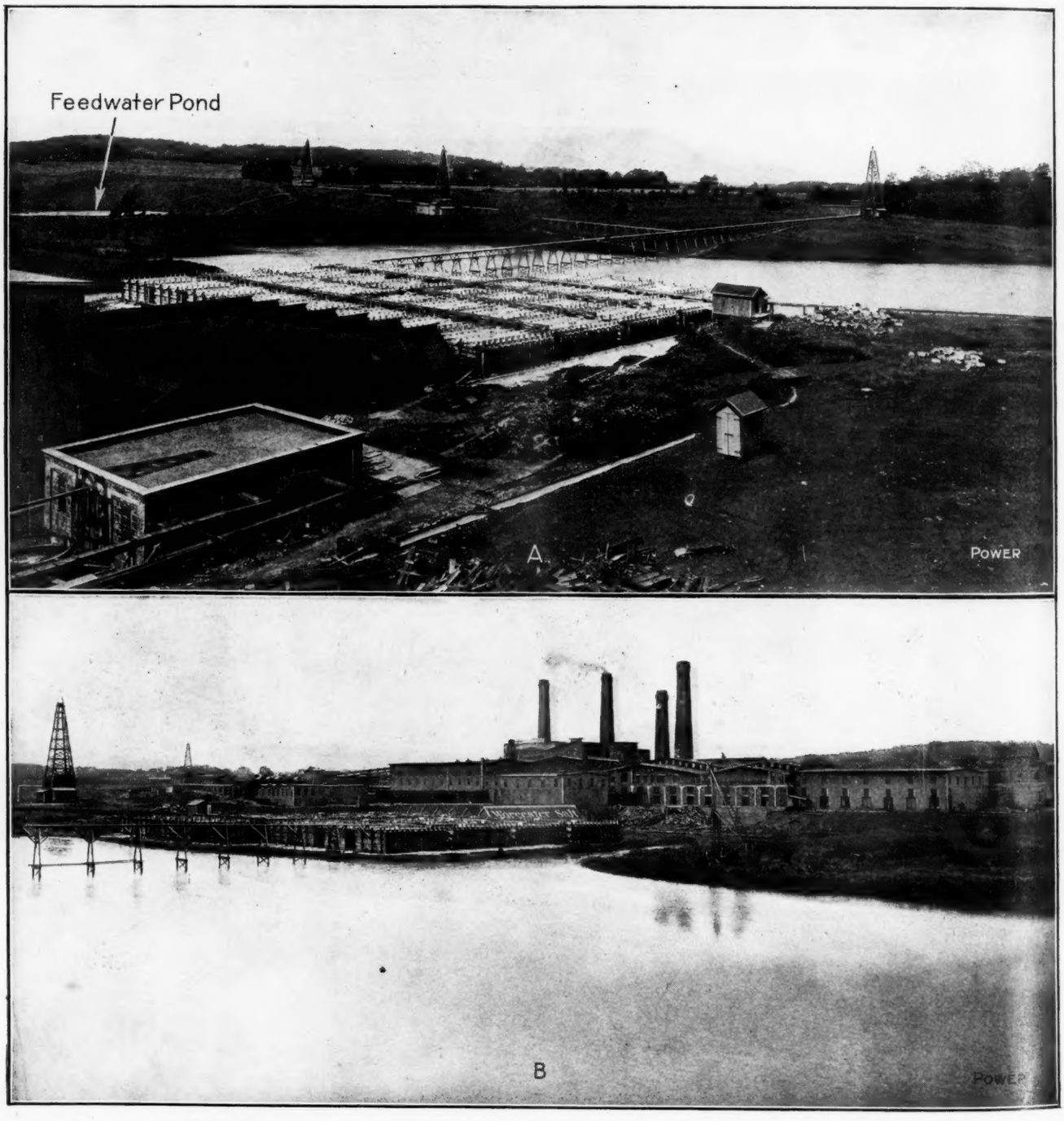


Fig. 1. (A) Feed-Water Pond, Salt Wells and Pump House; (B) Cooling Pond and Buildings

Boilers and Coal-Handling Equipment

As the brine taken from the wells must be evaporated, it will be realized that where 300 tons of salt is turned out daily, considerable steam is needed for evaporating and drying purposes. Steam is furnished by twenty-two horizontal tubular, stoker-fired boilers, fourteen of 200-hp. each and eight of 250 hp. each. Eight boilers are provided for high-pressure (115-lb.) service, three of which may be connected into the low-pressure (80-lb.) header; the others are used solely for furnishing steam at 80 lb. for heating and evaporating brine and for drying salt. Three boilers are kept in reserve to be used when the others are being cleaned or for emergencies.

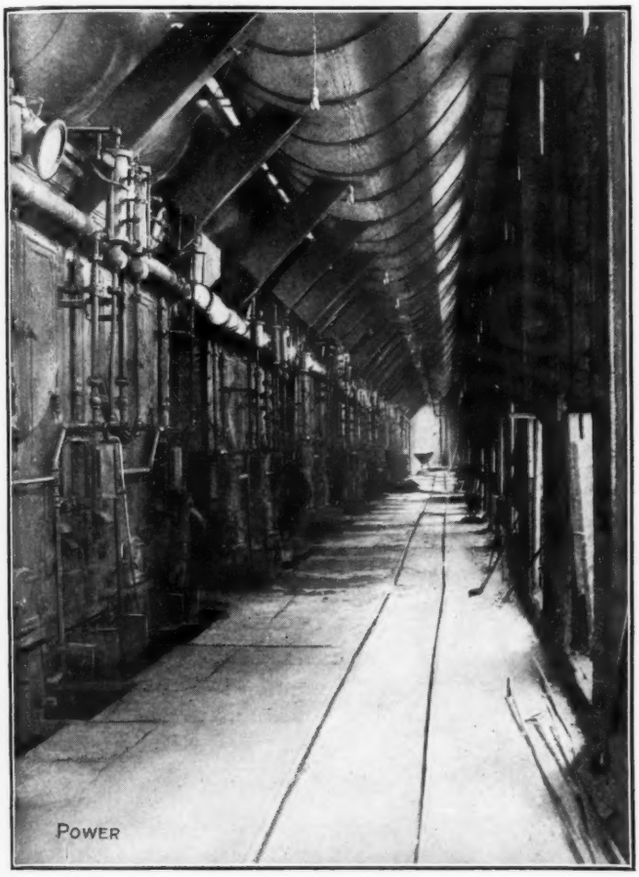


Fig. 2. Twenty-two Boilers; Suspended Coal Bunker 300 Ft. Long

A feature of the boiler house is the suspended coal bunker, Fig. 2, which is 300 ft. long and of 450 tons capacity. Bituminous slack is used as fuel and, as may be seen in Fig. 2, it must gravitate through the 8x13-in. rectangular chutes to the furnaces. Great as is the angle of inclination of these chutes, the slack will often stop in the chutes, especially if it is wet. This is a serious condition, owing to the little room available for making alterations.

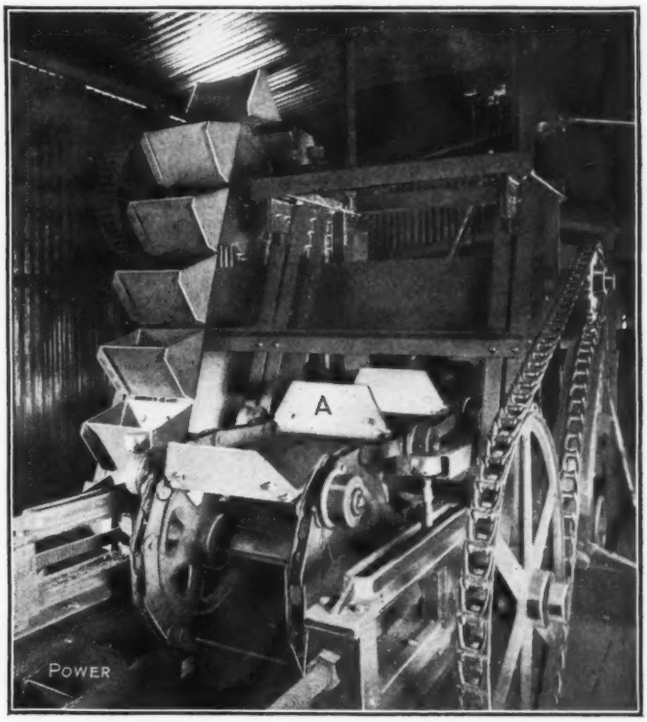


Fig. 3. View of Scraper and Bucket Conveyors

Coal is dropped direct from cars into a hopper under the coal trestle. Then it is taken on an apron conveyor

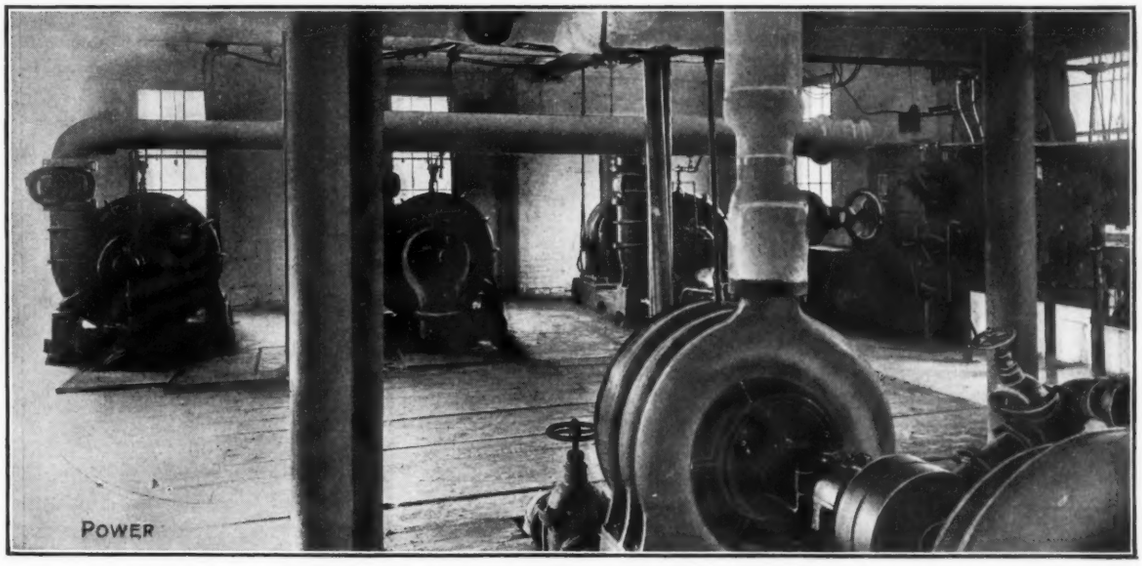


Fig. 4. Pump Room, All Pumps Motor-Driven, Centrifugal Type

to the crusher and by a bucket conveyor is elevated to the scraper conveyor above the bunker. Parts of both conveyors are shown in Fig. 3. As indicated by Fig. 3, the coal is distributed over the bunker by a scraper conveyor which runs in a trough, the coal being pushed along by the plates *A*. Coal is dropped into the bunker by opening sliding gates in the bottom of the trough. Operation of the conveyor has shown that the forward end of the trough wears through before the other end manifests any signs of wear. This condition prevails because all coal must be pushed over the forward end, no matter in what part of the 300-ft. bunker it is to be dumped. Originally, the trough was of ¼-in. steel throughout, but to avoid service interruptions occasioned by frequently renewing the worn parts, the thickness of the trough has been graduated from ½ in. at the forward end to ¼ in. at other end. This has been done because by the time the front or thicker end will have worn through, the thinner end will also have worn out. Experience is showing that this result can be better accomplished by graduating the thickness from ¾ in. to ¼ in.

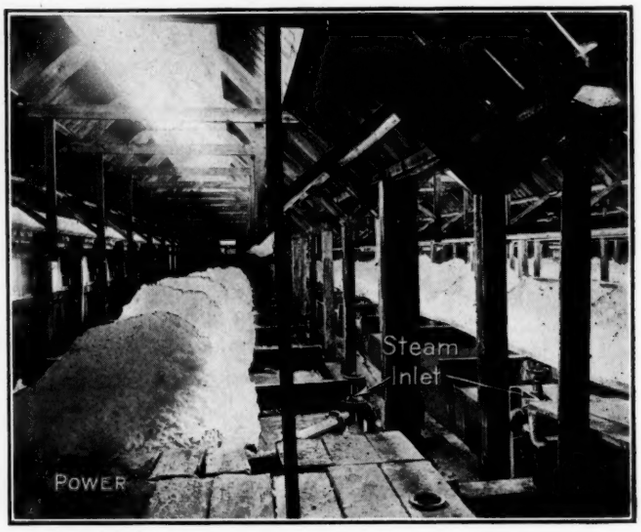


FIG. 5. GRAINER ROOM WHERE BRINE IS EVAPORATED AT ATMOSPHERIC PRESSURE

The ashes drop from the stokers into large steel boxes in the ashpits, the boxes being lifted out by a crane traveling on the track in front of the boilers. Wedge-shaped steel side-dump cars receive the ashes, the cars being emptied in what the men term the "inferno," because the great pile of ashes burns continuously.

FEED-WATER SYSTEM

The boiler-feed water and the fresh water for salt making are supplied from a creek running through the property and from five driven wells. There are two ponds holding feed water and one large pond for cooling the 7,000,000-gal. 24-hr. consumption for the vacuum-pan condensers. About 1,000,000 gal. of fresh water is used daily, making a total of 8,000,000 gal. to be pumped. The fresh-water wells, like the salt wells, are on different levels, and after the water is raised by air, it gravitates to the ponds. Two motor-driven, single-stage centrifugal pumps in the pump house, shown in the left foreground of the top picture, Fig. 1, deliver water from the ponds to a filter and heater, from which it goes to a large open heater tank receiving the returns. Fig. 4 is an interior view of this pump house.

The feed pumps are in the engine room, about 30 ft. from the point where the feed lines enter the boiler room. Originally, a reciprocating feed pump was used but vibration of the line to the boiler room made it necessary to anchor the line with tie-rods and turnbuckles. A turbine-driven centrifugal pump was later installed in the engine room with a separate line to the boiler-room main. There is no vibration in this line.

STEAM FOR EVAPORATING BRINE

An idea of the amount of low-pressure and exhaust steam needed for salt making is had from the fact that the 15 grainers (one is shown in Fig. 5), have a capacity of 200,000 lb. of salt daily. The four vacuum pans, operating under 28 in. vacuum, turn out 425,000 lb. daily, making a total of 625,000 lb. of salt obtained by evaporating brine. Large heating tanks of 75,000 gal. capacity each and having coils of 3-in. pipe, preheat the brine evaporated in the vacuum pans. Besides the steam used for evaporating brine, much is employed in drying the salt prior to packing. The salt grains produced by the vacuum-pan process are much finer than those made in the open grainers.

Motor-driven centrifugal pumps handle the brine, which gives considerable trouble by corroding the pump impellers and casings. As the head is low, the leaks in the casings are sometimes temporarily stopped with wooden plugs. The air for lifting the well water, both fresh and salt, is furnished by a 175-hp. compressor delivering air at 400-lb. pressure to a receiver, the pressure being reduced at the receiver. Four 20-hp. reciprocating dry-vacuum pumps take air from the condensers serving the vacuum pans.

ELECTRIC-GENERATING UNITS

The two Corliss engines, of 250 and 150 hp. respectively, are connected by rope drives, with a line shaft to direct-current generators of 150 and 100 kw. capacity for reserve service, and one 450-hp. Corliss engine is directly connected to a 250-kw. direct-current generator for normal service. All the units are noncondensing, the steam being used for industrial purposes.

The energy is distributed by electric transmission to 55 motors ranging from 2 to 60 hp. The air in some of the rooms in salt works contains much salt which settles like dust. Many of the motors at the Worcester plant are in such rooms and, although no special casings are provided and the field-pieces and armatures are coated with salt, they give little trouble. The commutators and brushes are given considerable attention. The electrical department is equipped to make all the necessary repairs and renewals. A reciprocating fire pump of 1000 gal. per min. capacity is connected to the fire-line system. A gong and indicator in the engine room enable the engineer to tell when and what sprinkler head has opened.

A well equipped laboratory consisting in part of indicators, CO_2 apparatus, a coal calorimeter, crucibles and furnaces, water-analysis outfits, etc., is maintained in connection with the company's plant.

The duties of chief engineer are combined with those of the assistant superintendent, who is directly responsible for the operation and maintenance of the entire works.

PRINCIPAL EQUIPMENT OF THE WORCESTER SALT CO.'S PLANT, SILVER SPRINGS, N. Y.

No.	Equipment	Kind	Size	Use	Operating Conditions	Manufacturer
14	Boilers	Horizontal tubular	200 hp.	Low pressure steam	Stoker fired, 80 lb.	McEwan Bros.
8	Boilers	Horizontal tubular	250 hp.	High pressure steam	Stoker fired, 115 lb.	McEwan Bros.
1	Engine G	Corliss-single	24x36 in., 450 hp.	Main unit	100 lb., 120 r.p.m., direct connected	Allis-Chalmers
1	Engine H	Corliss-single	16x38 in., 120 hp.	Main reserve unit	100 lb., 85 r.p.m., rope drive	Watts-Campbell
1	Engine I	Corliss-single	20x42 in., 200 hp.	Main reserve unit	100 lb., 80 r.p.m., rope drive	C. & G. Cooper Co.
1	Air compressor	Steam driven, double	Steam end, 2-16x30 in., Air end, 2-8½x18½x30 in.	Main air supply	100 lb., 75 r.p.m., 170 hp.	Air end: Ingersoll-Rand Co. Steam end: C. & G. Cooper Co.
1	Air compressor	Steam driven	Steam end: 20x24 in. Air end: 6½x13½x24 in.	Main reserve air supply	100 lb., 165 r.p.m., 150 hp.	Norwalk Iron Works
1	Pump J	Centrifugal	4-in., 2-stage	Boiler feed water	2750 r.p.m., turbine driven, 290 gal. p.m.	Jeansville Iron Works
1	Pump	Reciprocating	14x13x8 in.	Silos to filter to receiving tank	100 lb.	A. S. Cameron Steam Pump Co.
1	Pump	Reciprocating	2-18x10x12 in.	Fire mains	100 lb., 70 s.p.m., 1000 gal. per min.	Worthington Steam Pump Co.
1	Pump	Triplex	6x6½ in.	Pond to pond reserve	Motor driven	M. T. Davidson
2	Pumps A	Centrifugal	10-in. volute	Brine to vacuum pans	Motor driven, single stage, 850 r.p.m.	Worthington Steam Pump Co.
1	Pump	Reciprocating	16x8x18 in.	Boiler feed water reserve	100 lb., 261 gal. per min.	A. S. Cameron Steam Pump Co.
2	Pumps B	Centrifugal	4-in. turbine	Brine to grainers	Motor driven, single stage, 1500 r.p.m.	DeLaval Steam Turbine Co.
1	Pump C	Centrifugal	10-in. volute	Brine to vacuum pans	Motor driven, single stage, 850 r.p.m.	Worthington
1	Pump D	Centrifugal	4-in. turbine	Water to salt cavities	Motor driven, single stage, 1100 r.p.m.	Worthington
2	Pumps E	Centrifugal	4-in turbine	Condensing water to vacuum pans	Motor driven, single stage, 1400 r.p.m.	Worthington
1	Pump F	Centrifugal	6-in. turbine	Pond to pond (fresh)	Motor driven, single-stage, 1050 r.p.m.	Worthington
1	Pump	Locomotive	8x8 in.	Sprinkler system	Intermittent	Westinghouse Air Brake Co.
4	Pumps	Reciprocating-vacuum	12x18x18 in.	Vacuum for pans	100 lb., 75 r.p.m., 50 hp.	A. S. Cameron Steam Pump Co.
22	Stokers	Overfeed		Boiler furnaces	Bituminous slack	Murphy Iron Works
1	Coal bunker	Suspended, steel-concrete	300 ft. long	Coal storage	Scraper-conveyor filled	Guarantee Construction Co.
1	Coal conveyor over bunker K	Chain scraper convey	300 ft. long	Coal transfer	Bituminous slack, motor driven	Guarantee Construction Co
1	Floor track trav. crane	Boom	Steel	Ash lift from pits	Motor driven	Northern Engineering Co.
1	Feedwater heater	Closed	6' diam. x 13' long.		Exhaust steam	Hoppes Mfg. Co.
1	Turbine J	Impulse	2½" steam.	Boiler feed pump drive	100 lb., 2750 r.p.m., 56 hp., 290 gal. per min. at 300 ft. head	Terry Steam Turbine Co.
2	Filters	Reversible	5' diam. x 7' high	Feedwater		
1	Generator G	Direct current	300 kw.	Main unit	2500 amp., 120 volts, 120 r.p.m., direct connected	Allis-Chalmers Co.
1	Generator I	Direct current	150 kw.	Main reserve unit	1200 amp., 125 volts., 500 r.p.m., rope drive	General Electric Co.
1	Generator H	Direct current	96 kw.	Main reserve unit	800 amp., 120 volts, 600 r.p.m., rope drive	General Electric Co.
1	Switchboard	Direct control	7x10 feet	Main unit control		Worcester Salt Co.
1	Motor K	Direct current	20 hp.	Bucket, elevator and coal scraper conveyor	145 amp., 120 volts, 1100 r.p.m.	General Electric Co.
2	Motors E	Direct current	40 hp.	Condensing water to vacuum pans	110 amp., 120 volts, 1400 r.p.m.	Allis-Chalmers Co.
1	Motor D	Direct current	65 hp.	Fresh water to cavity	448 amp., 125 volts, 1100 r.p.m.	General Electric Co.
2	Motors A	Direct current	60 hp.	Brine to vacuum pans	450 amp., 125 volts, 850 r.p.m.	Western Electric Co.
1	Motor F	Direct current	7½ hp.	Pond to pond (fresh)	56 amp., 120 volts, 1050 r.p.m.	Sprague Electric Co.
2	Motors B	Direct current	20 hp.	Brine to grainers	145 amp., 120 volts, 1500 r.p.m.	Diehl Mfg. Co.
1	Motor C	Direct current	55 hp.	Brine to vacuum pans	420 amp., 110 volts, 845 r.p.m.	General Electric Co.
1	Apron conveyor L	Trestle hopper to coal crusher				Guarantee Construction Co
1	Bucket elev. K	Coal crusher to scraper conveyor				Guarantee Construction Co.
1	Motor L	Direct current	20 hp.	Coal crusher, apron conveyor and car puller	148 amp., 115 volts, 1100 r.p.m.	Sprague Electric Co.

Note:—Letters A and A, B and B, C and C, etc., indicate connected units.

Properties of Ammonia*

Ammonia, so called, because originally prepared from camels' dung, near the temple of Ammon, in Egypt, is a compound of hydrogen and nitrogen, having the chemical formula NH_3, which means that an atom of nitrogen (representing 14 parts by weight) is combined with three atoms of hydrogen (representing three parts by weight.) It is a colorless gas at ordinary temperatures and pressures, but at about —27 deg. F. it becomes liquid at the pressure of the atmosphere, and, of course, at higher temperatures if greater pressures are employed.

At about —110 deg. F., liquid ammonia turns into a white crystalline solid, and is almost without smell; at about 900 deg. F., ammonia dissociates—that is, it is decomposed into its constituents, nitrogen and hydrogen.

Ammonia gas is very soluble in water, the solution constituting the so called aqua ammonia that is employed in absorption systems. The capacity of water for absorbing ammonia gas varies with its temperature, but ordinarily it will take up from 500 to 800 times its own volume.

Following its discovery by an ancient alchemist, ammonia was in time manufactured through the destructive distillation of horns, hoofs, and hides, and its production from horns gave an early name to aqua ammonia of "spirits of hartshorn." Now ammonia is chiefly obtained as a byproduct in the manufacture of illuminating gas from coal and from the manufacture of coke in byproduct coke ovens.

Lately, the production of ammonia synthetically, using the nitrogen of the atmosphere, has engaged the attention of scientists. It is very doubtful, however, that the successful commercial production of synthetic anhydrous ammonia has yet been achieved. The anhydrous ammonia produced carries suspended in it uncombined nitrogen and hydrogen gases, and the cost of manufacture is probably greater than by the usual method. There is practically an unlimited demand for sulphate of ammonia as an agricultural fertilizer, and the synthetic manufacturers have this product immediately in mind rather than anhydrous and aqua ammonia for employment in refrigeration and ice-making.

Experienced operating refrigerating engineers know the desirability of employing in plants under their charge anhydrous ammonia that is free from uncombined nitrogen or hydrogen gases, which occupy condenser space that should be occupied only by ammonia gas, and being present, give rise to abnormal working pressures and impose the need of frequent purging to expel them.

Anhydrous ammonia, by reason of its adaptability to liquefy under comparatively low pressures, is the medium most generally employed in refrigerating and ice-making machines. As an indication of the growth of the industry it may be stated that in 1890, there were not more than 1000 ammonia-using refrigerating and ice-making plants in operation in the United States. At the present time there are at least 12,500 plants, while the increase of like plants in foreign countries, though not as rapid as in the United States, exhibits a healthy growth.

*Abstract of paper read by J. C. Atwood before the Practical Refrigerating Engineers' Association, Dallas, Tex.

Cost of Compressing Air by Electricity

By W. C. Lancaster

SYNOPSIS—Factors in determining the relative costs of compressing air by steam and by electricity. The figures for the latter are based on actual installations where a low rate for electricity is charged. The article applies chiefly to compressor plants used in construction work, where there are limitations of space, where the work is more or less of a temporary nature and where there is no use for exhaust steam.

The increase in the use of electricity as a motive power during the past decade has been the cause of marked improvement in air-compressor construction. During this period there has been a constantly increasing demand for large compressors which has resulted in the development of the modern high-speed, direct-connected electrically driven air compressors that are being used so universally at present.

Cheaper rates for electric power quoted by central stations and the saving in space effected by motor-driven compressors are largely responsible. A striking example

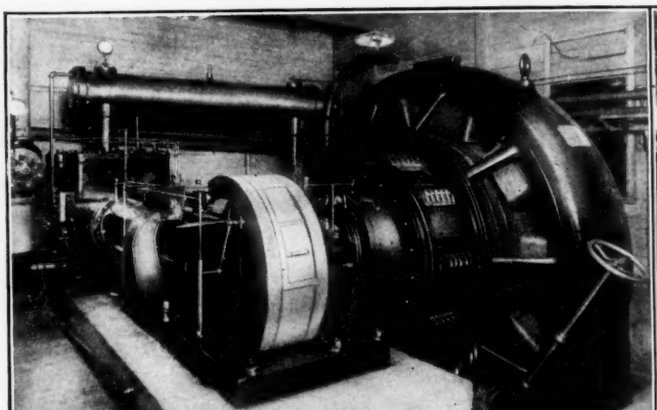


Fig. 1. Motor-Driven Compressor Used in Connection with Pennsylvania R.R. Tunnels

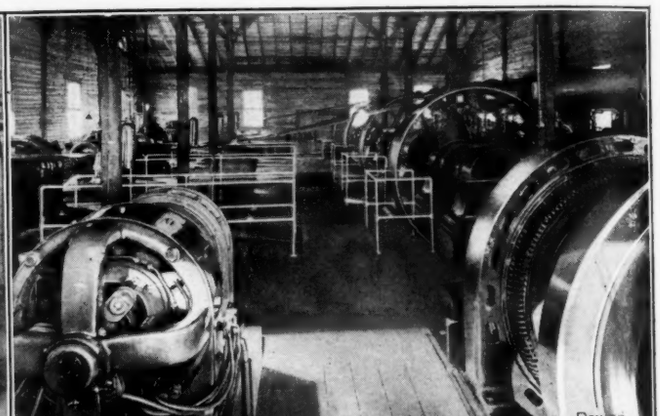


Fig. 3. Belted Compressors Referred to in "E," Table I

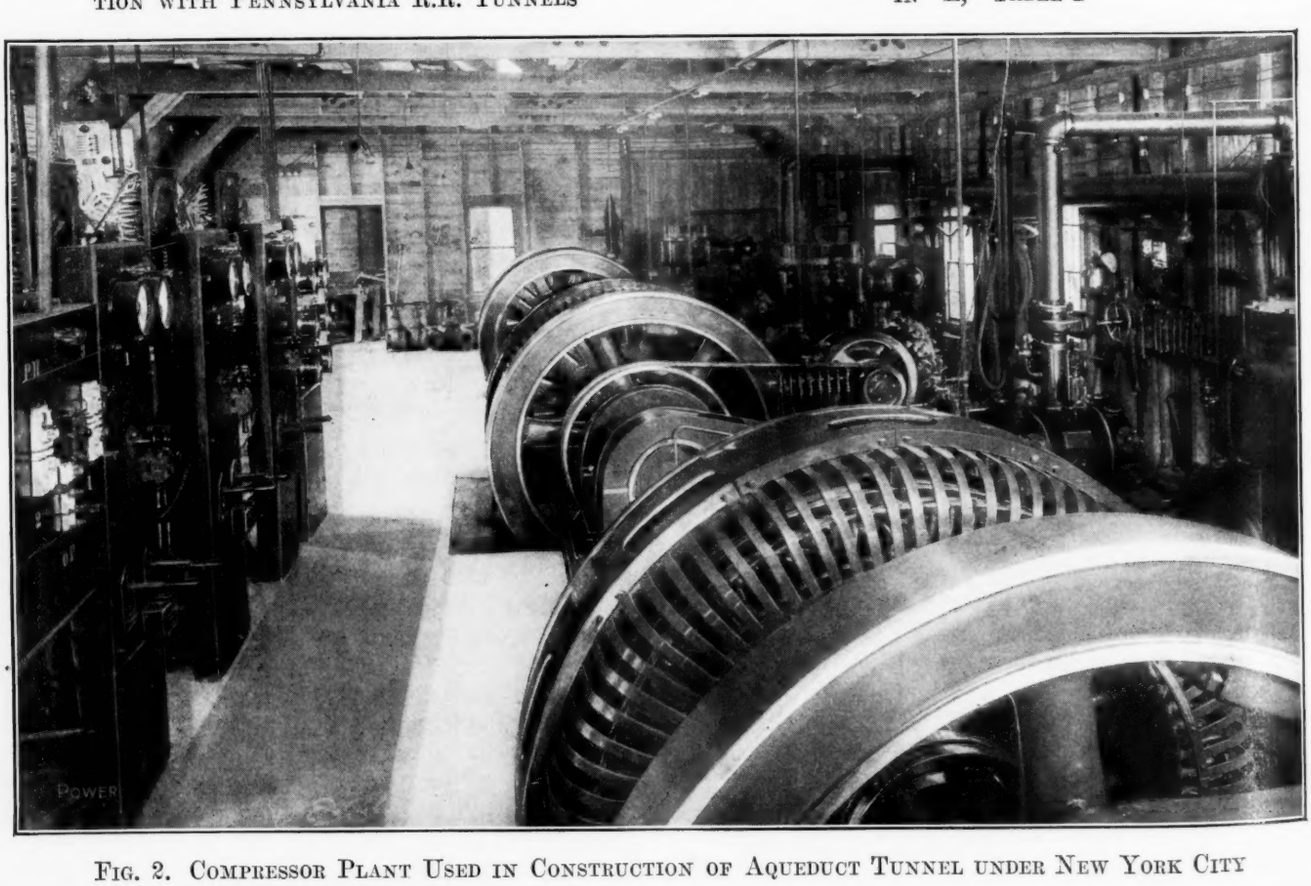


Fig. 2. Compressor Plant Used in Construction of Aqueduct Tunnel under New York City

of both of these is the plant installed by the writer in 1905 in connection with the construction of the Pennsylvania R.R. crosstown tunnels in New York City. This plant, a part of which is illustrated in Fig. 1, was located within one block of the Waldorf-Astoria. Property in this neighborhood was so expensive that the elimination of space for steam boilers and for the storage of coal was a necessity. Even with a high rate for electricity it would undoubtedly have figured less expensive to use electric compressors, but as a matter of fact a most attractive rate was obtainable from the New York Edison Co.

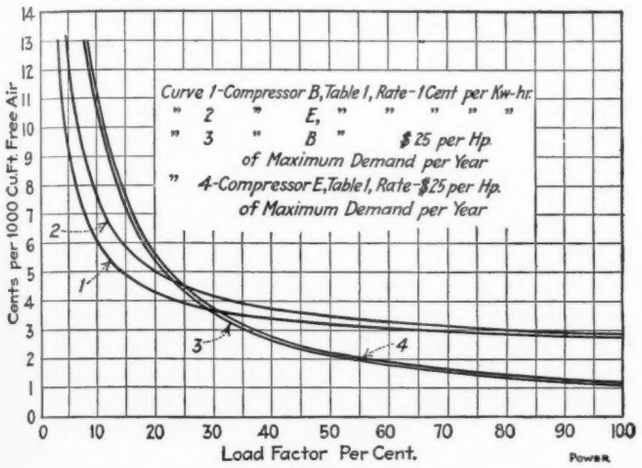

Curve 1-Compressor B, Table 1, Rate-1 Cent per Kw-hr.
" 2 " E, " " " " "
" 3 " B " $25 per Hp.
of Maximum Demand per Year
" 4-Compressor E, Table 1, Rate-$25 per Hp.
of Maximum Demand per Year
Cents per 1000 Cu.Ft. Free Air
Load Factor Per Cent.
POWER

FIG. 4. COST OF ELECTRICITY FOR COMPRESSING AIR AT DIFFERENT LOAD FACTORS

Other examples of the use of electric compressors where space is limited are the plants used for the construction of the Catskill Aqueduct under the City of New York. The contracts for this work required the use of electricity wherever possible in order to do away with the noise and dirt incident to steam plants; besides this, the space furnished the contractors around each shaft for the plant was so limited that electric-driven compressors had to be used in almost every case. One of these plants, also installed by the writer, is illustrated in Fig. 2.

The first air compressors to be driven by electricity were either belted or geared to the motor. This drive is still used for compressors of small size and also for the larger sizes where electric power is cheap, or where the installation is only temporary. Sometimes even for air plants on construction work that will be completed in two to three years, it pays when the rate charged for electric power is high, to use the more expensive direct-connected machines.

The question of whether an air-compressor plant had better be operated by steam or electricity depends upon so many variables that it is impossible to give a general rule to cover all cases. Each must be worked out individually, taking all the local conditions into careful consideration and balancing the first cost and operating cost of each, comparing the steam and electric operation about as follows:

Steam	Electric
First cost:	
Compressors and engines	Compressors and motors
Boilers	
Stokers	
Economizers	
Feed-water heaters	
Condensers	
Pumps	
Compressed-air piping	Compressed-air piping
Steam piping	
Cooling-water piping, pump and tanks	Cooling-water piping, pump and tanks
Coal-handling machinery	
Coal-storage bunkers	
Ash-removal machinery	
Building and foundations	Building and foundations
Stack or mechanical draft	
Land	Land
Operating cost:	
Fixed charges, including interest, taxes, insurance and depreciation	Fixed charges, including interest, taxes, insurance and depreciation
Coal for operating compressors and auxiliaries	Electricity for operating compressors
Coal for heating building	Coal for heating building
Coal handling	
Ash removal	
Water for boilers	
Water for condensers	
Water for compressor jackets	Water for compressor jackets
Oil for air cylinders	Oil for air cylinders
Oil for steam cylinders	
Oil for guides and pistons (and crankshaft if cross-compound)	Oil for guides, pistons and crankshaft bearings (same as motor bearings if direct connected cross-compound)
Waste	Waste
Repairs	Repairs
Labor in compressor room	Labor in compressor room
Labor in boiler room	

In figuring the cost, of course, the type of plant must be chosen that seems to best suit the conditions of the problem in hand. For steam the principal questions to

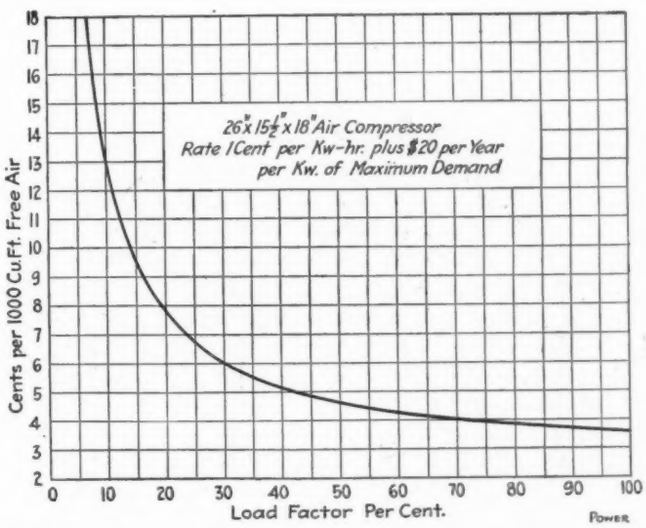

26"x15½"x18" Air Compressor
Rate 1 Cent per Kw-hr. plus $20 per Year
per Kw. of Maximum Demand
Cents per 1000 Cu.Ft. Free Air
Load Factor Per Cent.
POWER

FIG. 5. COST OF ELECTRICITY FOR COMPRESSING 1000 CU.FT. OF FREE AIR AT DIFFERENT LOAD FACTORS—COMPRESSOR C, TABLE I

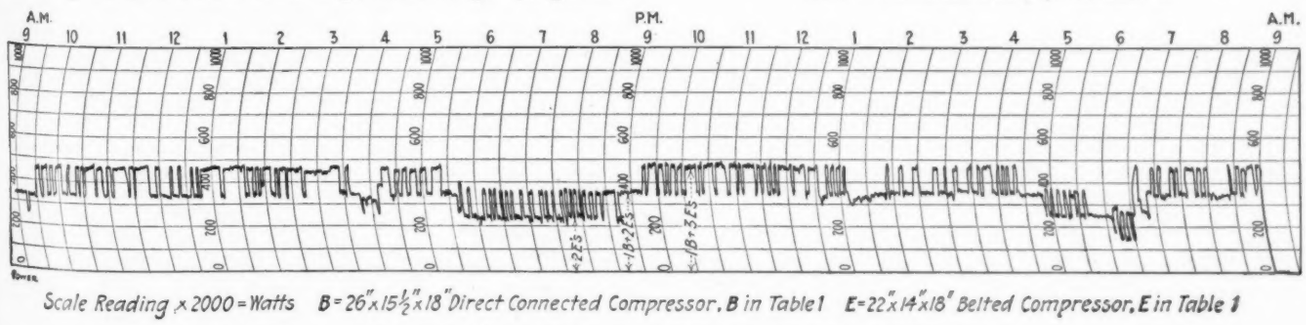

A.M.
P.M.
A.M.
Scale Reading x 2000 = Watts
B = 26"x15½"x18" Direct Connected Compressor, B in Table 1
E = 22"x14"x18" Belted Compressor, E in Table 1

FIG. 6. LOAD CHART OF TYPICAL 24-HR. RUN

be decided are whether the plant is to be condensing or noncondensing, and whether the compressors are to be of the simple steam, compound-air type, or the compound-steam, compound-air type. For the electric plant the main point to be decided is whether the compressors are to be belt driven or directly connected to the motors.

Estimates of the first cost of both steam and electric compressor plants are easily computed, and so many steam plants have been installed that both their first cost and operating cost have been carefully worked out and are very well known to engineers and contractors who have to do with plants of this nature.

But as regards the cost of electric power required to deliver a given amount of compressed air, there seems to be some uncertainty as well as a considerable lack of published data on the subject.

In the Jan. 6, 1914, issue of POWER, the writer gave a method of testing electric-driven air compressors and the results of a test on a large unit. Some similar test results are given in Table 1.

TABLE 1. AIR-COMPRESSOR TESTS

Compressor	Size	Speed r.p.m.	Piston Displacement Cu.Ft. per Min.	Discharge Air Pressure Lb. per Sq.In.	Volumetric Efficiency Per Cent.	Horsepower Input per 100 Cu.Ft. per Min. Free Air	Kilowatt-hours per 1000 cu.ft. of Free Air	Horsepower Input No Load	Drive
A	26x15½x18	185.5	2042.5	100	85.1	22.85	2.85	53.1	Direct-connected
B	26x15½x18	185.3	2039.7	100	86.5	22.75	2.83	51.0	Direct-connected
C	26x15½x18	188	2070	100	88.0	23.26	2.91	56.6	Direct-connected
D	25½x15½x21	188	2117	100	79.2	23.89	2.99	60.3	Direct-connected
E	22x14x18	157.8	1241.2	100	88.6	23.7	2.94	46.0	Belted

It will be noted that the first three machines are of the same size. They are also of the same type and the volumetric efficiencies and other characteristics check very closely.

Compressor D is of very nearly the same size and speed as the first three, but is of a different type and driven by

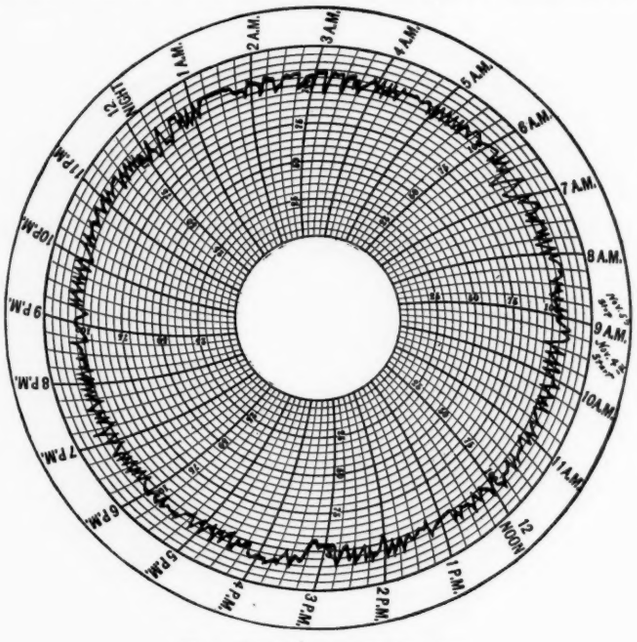


FIG. 7. PRESSURE CHART

a different make of electric motor, either or both of which facts may account for its lower volumetric efficiency and somewhat greater input per 100 cu.ft. per min. of free air.

The speed of compressor E is lower and this undoubtedly accounts for its higher volumetric efficiency. Being a considerably smaller machine this efficiency would probably be somewhat lower if the speed were the same as the others. Although belt-driven, the economy as regards electric-power input per 100 cu.ft. of air is very little higher than the larger direct-connected machines. This is partly due to the higher volumetric efficiency and partly to the exceptionally good belt drive. The belt is wide and heavy and there is ample distance between driving and driven pulleys, so that there is probably very little power lost. Four of these belted compressors and motors are shown in Fig. 3.

The cost of electricity for compressing air depends on three things:

1. The power input per cubic foot of air output required by the compressors, or "power efficiency" as it might be called.
2. The load factor of the plant.
3. The rate charged for electricity.

The first of these, or the "power efficiency," has already been discussed. In making an estimate of the cost of electric power for a given plant a value for this power efficiency must be assumed, and this can be based either on test data similar to that given in Table 1, or upon the guarantee of a reliable manufacturer. Care must be taken in selecting this value that the test or guarantee from which it is obtained is on a compressor of exactly or very nearly the same size, type and speed, as a considerable difference in any of these will sometimes change the power efficiency materially.

By "load factor" is meant the ratio of the actual output of compressed air from the plant in a given period of time, to the total output that the plant is capable of making in that time. The effect on the energy required to do useful work is evident when it is remembered that electrically driven air compressors unlike those driven by steam, run at constant speed whether loaded or unloaded and therefore the energy required during the time they are running unloaded and doing no useful work adds more and more to the energy input per cubic foot of air output as the load factor decreases. This effect on the economy of operation is small except at very low load factors, as can be noted from Figs. 4 and 5.

It is rather difficult to predict in advance just what this load factor will be. The best way to arrive at it is perhaps to compare the plant under consideration with other plants already built which are doing similar work and whose load factors are known.

In well designed plants furnishing compressed air for rock drills, pumps, etc., where the work is carried on day and night, the writer has found that the load factor usually runs well over 50 per cent., in some cases even reaching 80 per cent. For instance, the load curve given in Fig. 6 is a typical 24-hr. run taken in the plant illustrated in Fig. 3. The load factor for this run figures 78½ per cent.

The rate charged for electricity has the most important bearing of all upon the operating cost of electrically driven air compressors. These rates vary in different localities between rather wide limits. Usually the rate is either so many cents per kilowatt-hour; so many dollars

per horsepower (or kilowatt) of maximum demand per year; or some combination of these two.

To illustrate the effect of the power efficiency, load factor and rate on the cost of power, curves have been worked out with load factor as abscissas and cost of compressed air as ordinates. Curve 1, Fig. 4, shows how the cost for electric power per 1000 cu.ft. of free air, compressed to 100 lb. gage by compressor B, Table 1, varies with the load factor when the rate for electric power is 1c. per kw.-hr. This curve is figured as follows:

Compressor capacity = 1764.75 cu.ft. per min.
Yearly output = 1764.75 × 365 × 24 × 60 = 927,553,600 cu.ft. per yr.
Compressor input = 299.5 kw.
Kw.-hr. per year = 299.5 × 8760 = 2,623,620
At 1c. per kw.-hr., yearly cost = $26,236.20
Cost per 1000 cu.ft. = $26,236.20 ÷ 927,553.6 = $0.0283

This is at 100 per cent. load factor. Values at other load factors are obtained from the equation,

$$x = \frac{26{,}236.20\,y + 3328.8\,(1.00 - y)}{927{,}553.6\,y}$$

where

x = Cost in dollars per 1000 cu.ft.;
y = Load factor expressed as a decimal.

The second term of the numerator is the cost when the compressor is running idle. With the input at no load, equal to 38 kw., the yearly cost at no load would be

$$38 \times 8760 \times 0.01 = 3328.80$$

and during the actual no-load period would be

$$3328.8 \times (1.00 - y)$$

The other curves in Fig. 4 are drawn in a similar way. Curve 2 is for a 22x14x18-in. belted compressor (E in Table 1) with the same rate for power.

Curves 3 and 4 are for the same machines, but are based on a rate for electric power of $25 per hp. of maximum demand per year. It will be noted that at low load factors the 1c. rate is better, but not so good at the higher load factors.

The rate for power paid by the contractors who are building the sections of the Catskill Aqueduct under the City of New York is 1c. per kw.-hr. plus $20 per year per kilowatt of maximum demand. The curve in Fig. 5 is worked out on this basis. It is figured from the results of a test on one of the three compressors shown in Fig. 2 (compressor C, Table 1).

In order to give some idea of the total cost of compressing air the plant illustrated in Fig. 3 will be used as an example. Cost figures are given in Table 2. This plant consists of four 22x14x18-in., two-stage, cross-compound compressors belt driven by induction motors, and one 26x15½x18-in. compressor of the same type, but direct connected to a synchronous motor. The belted machines are each rated at 1240 cu.ft. per min. displacement, and the direct-connected machine at 2040 cu.ft. per min. One of the small compressors is held in reserve as a spare, so that the maximum number run at one time consists of the large machine and three small ones. Thus the total rated displacement of the plant is 5760 cu.ft. of free air per min. From the test results the actual total output is 5065 cu.ft. of free air per minute.

This plant is in Canada at the West Portal of the tunnel now under construction for the Canadian Northern R.R. and has been in operation about 16 months. The compressors were manufactured in the United States and a high duty had to be paid on them. The first cost given in Table 2 for the plant is therefore high compared with a similar plant in the United States. The figures for water, wages, supplies and repairs are the averages for the five months from June to October, inclusive.

The actual rate paid for electric power for this plant is rather complicated and would not serve as an illustration as well as a straight meter rate. An assumed rate of 1c. per kw.-hr. has therefore been used.

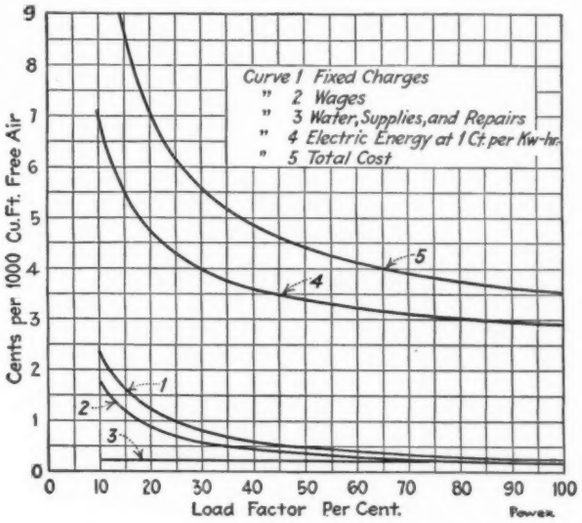

Curve 1 Fixed Charges
" 2 Wages
" 3 Water, Supplies, and Repairs
" 4 Electric Energy at 1 Ct. per Kw-hr.
" 5 Total Cost
Cents per 1000 Cu.Ft. Free Air
Load Factor Per Cent.
Power.

FIG. 8. TOTAL COST OF COMPRESSING 1000 CU.FT. OF FREE AIR AT DIFFERENT LOAD FACTORS—PLANT IN TABLE 2

A typical 24-hr. run is shown in Fig. 6. This chart was taken by means of a recording wattmeter connected so that the total power input to all the compressors was recorded. The maximum input is 924 kw. and the average 724 kw. The load factor for this day is therefore 78½ per cent. The pressure chart in Fig. 7 was taken at the same time that the load curve of Fig. 6 was made and shows an average pressure for the 24 hr. of 107 lb.

TABLE 2.

First Cost—		Cost
Cost of the five compressors, including motors and switchboard		$31,000
Piping, aftercooler and air receiver		3,000
Building and foundations (land not included)		2,700
Installing		2,300
Total		$39,000
Yearly Cost—		
Fixed charges—		
Interest on investment $39,000 × 6% =	$2340	
Taxes, 1% on land and building	200	
Insurance @ 20c. per $100 per year	78	
Depreciation, at 10% per year	3900	
Total yearly fixed charges		$6518
Operating charges—		
Power on basis of load curve of Fig. 6, giving load factor of 78½%		$63,422
Water, average daily consumption 7000 cu.ft., or $200 per mo. @ 10c. per 100 cu.ft.		2,400
Wages, average $400 per mo. for three 8-hr. shifts		4,800
Supplies, such as oil, waste, etc., average per month $103		1,236
Repairs, average per month, $49		588
Total operating charges		72,446
Total yearly cost		$78,964

The curves in Fig. 8 have been worked out to show how the total cost per 1000 cu.ft. of air varies with the load factor for the plant under consideration. Curve 1 shows the fixed charges. It is figured simply by dividing $6518 by the yearly output at the different load factors in thousands of cubic feet of free air. Curve 2 is similarly figured for wages only. The cost of water, supplies and repairs is assumed to vary in proportion to the load factor and therefore the cost of these items per 1000 cu.ft. of air is constant, as can be seen from Curve 3.

The cost for electric power based on a rate of 1c. per kw.-hr. is given by Curve 4. At low load factors this is slightly higher than would actually be the case in prac-

tice as the compressors would be shut down one after another as the load factor decreased instead of being run for any length of time at no load. For these calculations, however, in order to avoid breaks in the curve, the whole plant has been treated as though it consisted of one machine of the average economy of the four.

The total cost of 1000 cu.ft. of free air compressed to 107 lb. per sq.in. in this plant at various load factors is given in Curve 5, which is the sum of the ordinates of all the other curves, 1 to 4 inclusive.

Oil-Burning-Furnace Design

By J. J. McIntosh

SYNOPSIS—The omission of checker work and target walls is recommended. A number of furnaces applied to different boilers are illustrated.

The most important feature of an oil-burning system is the furnace arrangement. Poor economy is often due to improper furnace conditions, and upon the design of the furnace depends to a great extent the capacity of the boiler. If the furnace design is correct a 200 per cent. overload can be carried without injuring the boiler. The practice of using firebrick arches, checker work, target walls, etc., is unnecessary and is frequently the cause of the burning out of tubes or bagging the boiler. With such arrangements the cost of furnace repairs becomes high and they are likewise the cause of interruptions in service. The furnace should be designed so that the flame will not impinge on either the boiler or brickwork. The disastrous effects of the blowpipe action of the oil flame on the metal of boilers has become well known to engineers, but unfortunately many found it out too late. To secure the best results for burning oil, the furnace must be so arranged that, first, all air must pass through the flame; secondly, that the atomized oil must be completely burned while suspended in the air; third, that a large surface of brickwork be exposed near the flame; and, fourth, the flame must be distributed over a large area.

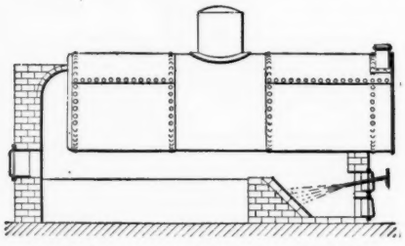


Fig. 1. Tubular Boiler with Target

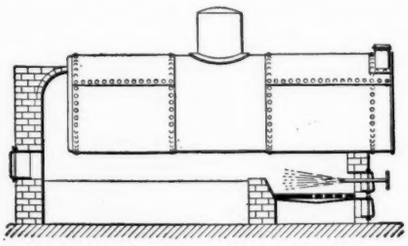


Fig. 2. Another Furnace Open to Objection

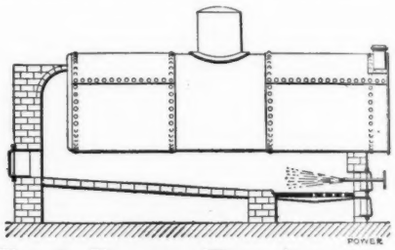


Fig. 3. Furnace Well Adapted for Tubular Boiler

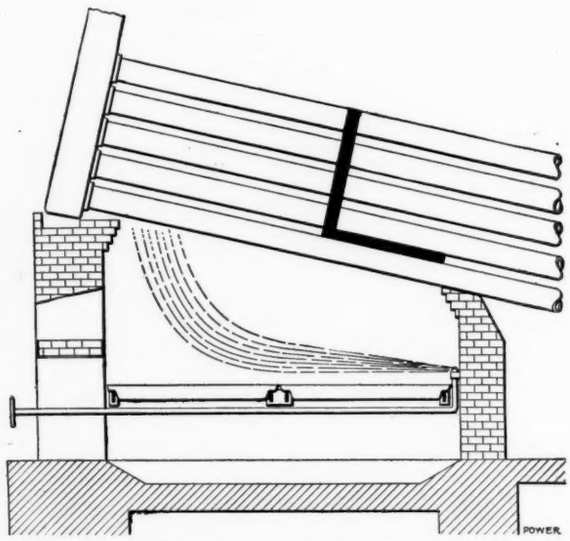


Fig. 4. Peabody Burner for B. & W. Boiler

Before going further, it might be well to state that the melting out of firebrick in an oil furnace may not always be caused by the heat alone, but is sometimes due to certain agents present in some oils which cause a fluxing action and melt the brick in a short time.

Fig. 1 shows a return-tubular boiler with the furnace arranged with a target. As was stated above, this type of oil furnace is liable to injure the boiler.

Fig. 2 is another arrangement of oil furnace for a return-tubular boiler. Although this type of furnace is still used to a certain extent, it is open to the same objections as the arrangement in Fig. 1, especially when

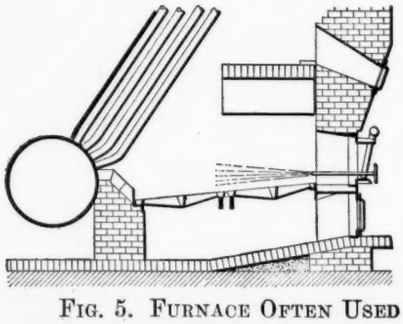


Fig. 5. Furnace Often Used with Stirling Boiler

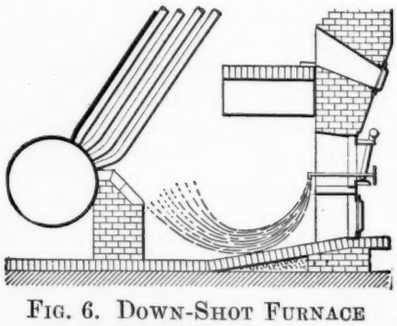


Fig. 6. Down-Shot Furnace for Stirling Boiler

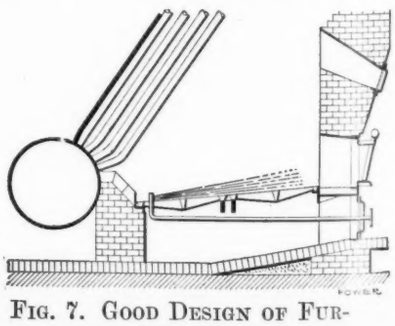


Fig. 7. Good Design of Furnace for Stirling Boiler

the boiler is forced. This brings to mind the case of a plant using four return-tubular boilers fired with oil and using a furnace arranged as in Fig. 2. In less than two months after changing from coal to oil the plant had to be shut down to repair the boilers.

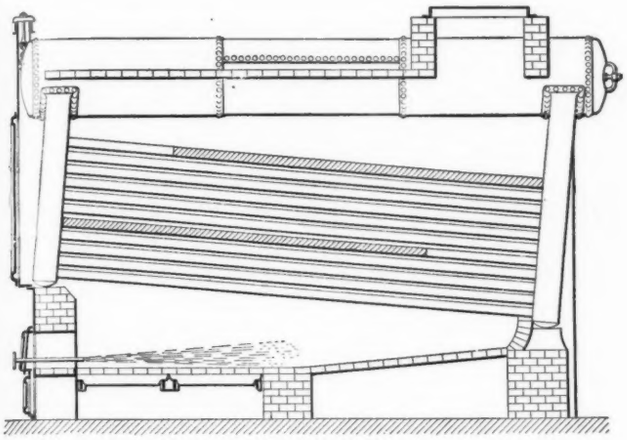


FIG. 8. FURNACE IN EDGE MOOR BOILER

Practice has demonstrated the design of furnace shown in Fig. 3 to be well adapted for burning oil under this type of boiler.

Fig. 4 illustrates a Babcock & Wilcox boiler fitted with a Peabody oil furnace. The furnace is fired from the

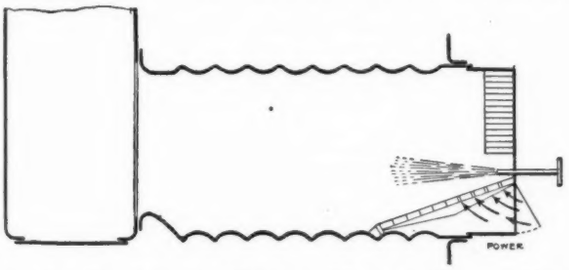


FIG. 10. FURNACE IN SCOTCH MARINE BOILER USING FISHTAIL BURNER

bridge-wall forward, but is controlled from the boiler front and is commonly termed the "forward-shot" furnace. This arrangement of oil furnace has given excellent results.

Fig. 5 shows a Stirling boiler with a furnace for oil

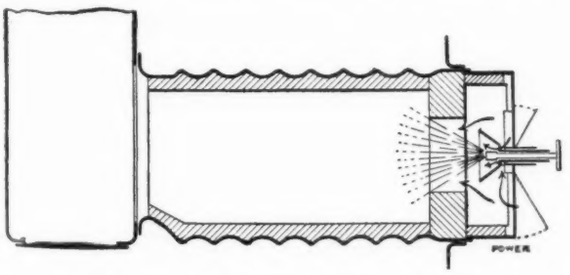


FIG. 11. SCOTCH MARINE BOILER EQUIPPED WITH MECHANICAL BURNER

that is used to a considerable extent. It is open to the objection that under heavy loads the flame is liable to impinge directly against the tubes. In Fig. 6 is shown a "down-shot" type of oil furnace with a Stirling boiler.

Fig. 7 is probably the best design of oil furnace for this type of boiler. It is, of course, understood that with this type of furnace the lining of the front is heavily reinforced with firebrick.

Figs. 8 and 9 illustrate Edge-Moor and Risdon water-tube boilers of the horizontal-pass type, fitted up for burning oil. In boilers of this make with a cross-pass

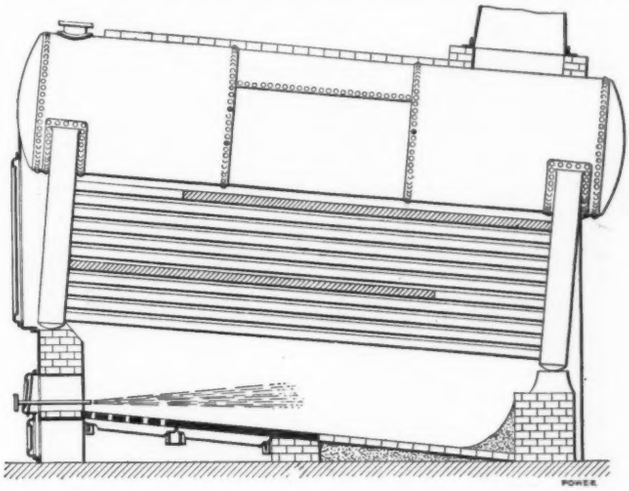


FIG. 9. RISDON BOILER EQUIPPED FOR OIL BURNING

setting, the correct furnace arrangement would be one similar to that applied to the Babcock & Wilcox boiler shown in Fig. 4.

In Fig. 10 is shown the furnace arrangement of a Scotch marine boiler using a fish-tail burner.

Fig. 11 illustrates the same type of boiler using a me-

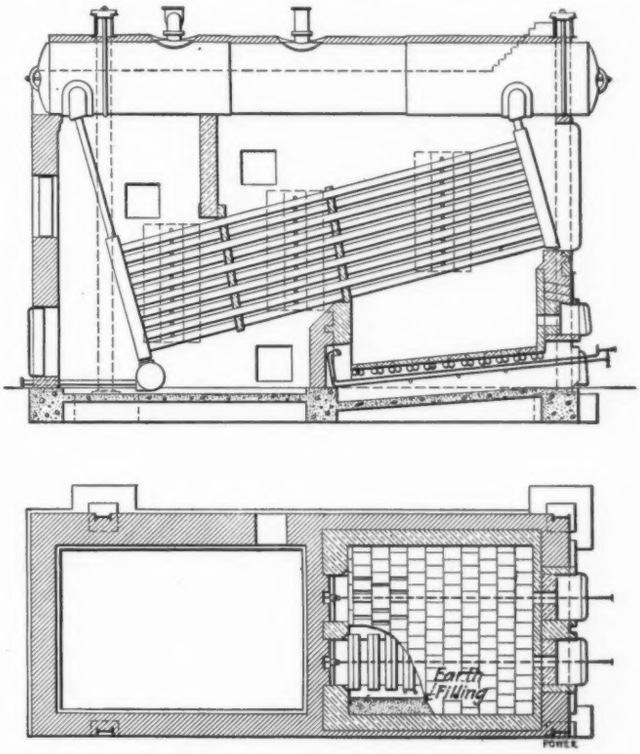


FIG. 12. HAMMEL BURNER AND B. & W. BOILER

chanical burner producing a round flame. Using the arrangement shown, the mechanical burner with a round flame gives excellent results.

Figs. 12 and 13 illustrate the Hammel oil-burning furnace as applied to the Babcock & Wilcox and Stirling water-tube boilers. In the construction of this furnace

each burner has an independent air supply. With a boiler using two or more burners, it is possible with this furnace to completely cut off the air supply to any burner

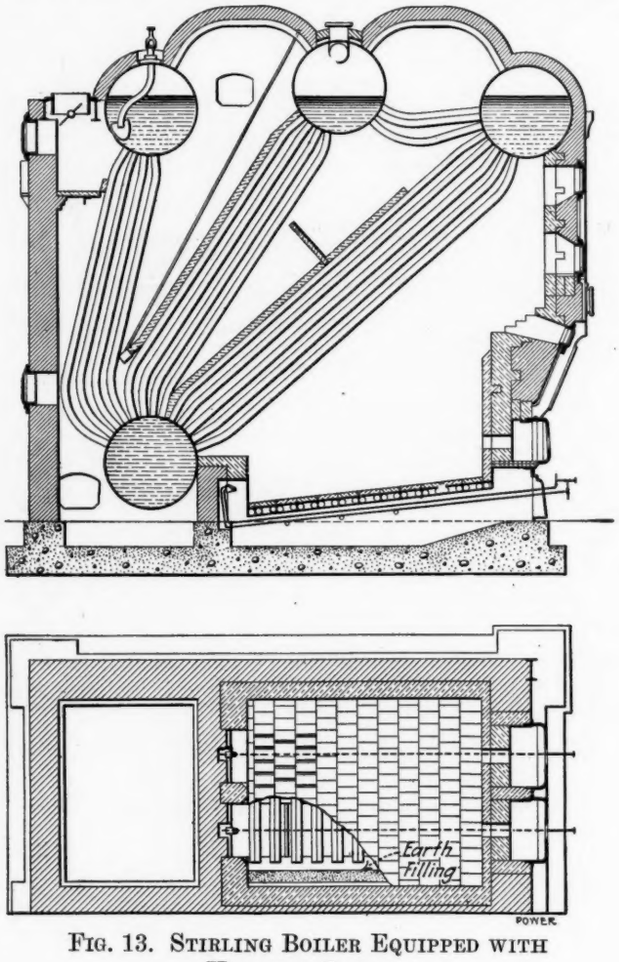


FIG. 13. STIRLING BOILER EQUIPPED WITH HAMMEL BURNER

that may be extinguished due to load conditions or for standby service, and not interfere with the burner or burners in operation.

Undesirable Power-Plant Conditions

BY C. O. SANDSTROM

Probably no power plant in this country, in design and equipment, is above honest criticism, and the designing engineer being human, and consequently fallible, commits errors of judgment which are sometimes supplemented by errors of information. Of course, these things are found less frequently in the larger plants, because the expenditure of a large sum of money justifies and necessitates the services of competent engineers.

Last summer the writer studied the design of a manufacturing plant in the Middle West, which for monstrosities was a veritable chamber of horrors, and, as an educational factor, was in the first rank. The power plant contains six 410-hp. water-tube boilers and two 800-kw. generators, driven by cross-compound condensing Corliss engines.

At first sight, this plant appears to be of usual design, but a superficial examination discloses details that render it a failure from an operating standpoint. When the plant was built, about six years ago, there were installed three boilers and one generator, but the boiler plant did not take care of the load and a fourth boiler was installed. Later, when the second generator was put in, two more boilers were added. Although but one generator was run at capacity, the behavior of the boiler plant indicated that if both generators were operated, the boiler capacity would be inadequate.

The condensing equipment consists of two siphon condensers (the injection inlets are about 45 ft. above the hotwell) served from a cross-connection in the piping by a 10 and 14 by 10-in. duplex steam pump. This pump, located about 500 ft. from the power house, took its water through some 300 ft. of pipe from a pond, the total head being about 70 ft. The exhaust was allowed to escape to the atmosphere. In times of high-temperature circulating-water, when full load came on the engine, the water required was above the capacity of the pump, and frequently the engine was operated on an 18-in. vacuum.

The feed-water heater, of the open type, would probably handle 500 hp. It was foisted upon the concern by a salesman who asserted that it was capable of heating the feed water for 1200 boiler horsepower. No one being the wiser, it was installed, and the trouble began. The exhaust from the auxiliaries was led to the heater, and in an attempt to raise the feed-water temperature above 130 deg. (which seemed to be the limit) by using all the exhaust from the exciter engine, large quantities of steam and water were blown out to the air.

In the suction line from the heater to the boiler-feed pump is a check valve for which the present engineer could find no use, so he removed the disk, thus eliminating a restriction to the flow. The 18-in. steam header is back of the double-drum boilers, which are connected to the header by 5-in. branches, one to each drum. There is a stop valve in each branch at the boiler nozzles. About 30 ft. of one end of the header has never been covered, and the heat loss, added to that from the remainder of so large a header, has been considerable, as was evidenced by the continual working of the traps.

The boiler-feed main terminates at one end of the row of boilers in a manifold, the branches running down behind the boilers in a confusion of piping.

The three boilers originally installed were connected to an 8x100-ft., guyed, steel stack, by a 6x3-ft. brick-lined underground flue. Owing to the insufficient height of the stack, aggravated by the small flue area, the boilers could not be run to their capacity, but if a test had been run, the cause of the trouble might have been ascertained. Instead, another boiler was installed which, of course, did not improve the draft conditions.

When the fifth and sixth boilers were added, they were connected to a flue running parallel with the old one and between the first boiler; and the stack was brought into the old flue at right angles. This resulted in more than 2400 boiler horsepower, connected to an 8x100-ft. stack by a 6x3-ft. flue.

Lighting Contract for Portland—The Portland Railway, Light & Power Co., after competitive bidding, has been awarded a contract for lighting the streets of Portland, Ore., for a period of three years beginning Jan. 1, 1914. The company recently completed the installation of a 10,000-hp. turbine, giving a total generating capacity of 90,000 hp. Twelve cities and towns in Oregon and Washington, having a total population of approximately 300,000, are now being supplied by the company.

Solving the Cinder Problem at Waterside--II

By Charles H. Bromley

SYNOPSIS—This second article in the series describes the original boiler-flue arrangement at Waterside Station No. 2. An average of 2000 tons of coal is burned daily on a ground area of 600x300 ft. A sawtoothed-shaped screen swept with air brushes passes through the base of the stack to intercept the cinder.

Original Flue Arrangement at Waterside

At Waterside No. 2 station, where nearly all the experimental cinder-catching apparatus was tried out, there are 96 boilers of 650 hp. each on two floors, 48 boilers to a floor, each floor having eight horizontal flues, each 50 ft. long by 9 ft. wide and receiving the gases from six boilers placed back to back, three in a row. There are four steel smokestacks, each 264 ft. in height above the grates of the boilers on the second floor. The stacks were made 100 ft. higher than those at Waterside No. 1, chiefly to discharge the cinder high enough for the prevailing northwest winds, which blow for 33 per cent. of the time at that place, to carry most of the cinder above the East River before it could settle.

2000 Tons Burned Daily in Space 600x300 Ft.

Waterside No. 1 station has 54 boilers on two floors, 28 on the first floor and 26 on the second. Usually there are 90 boilers in service and standing-by in both stations at all times.

The daily average coal consumption for both plants is 2000 tons. As in all central stations, severe load fluctuations must be cared for. A few of the storm peaks were shown in Figs. 2 and 3 of the issue of Jan. 27.

Think of it! An average of 2000 tons of coal per day burned on an area approximately 600x300 ft., and located in a congested part of Manhattan. No wonder the

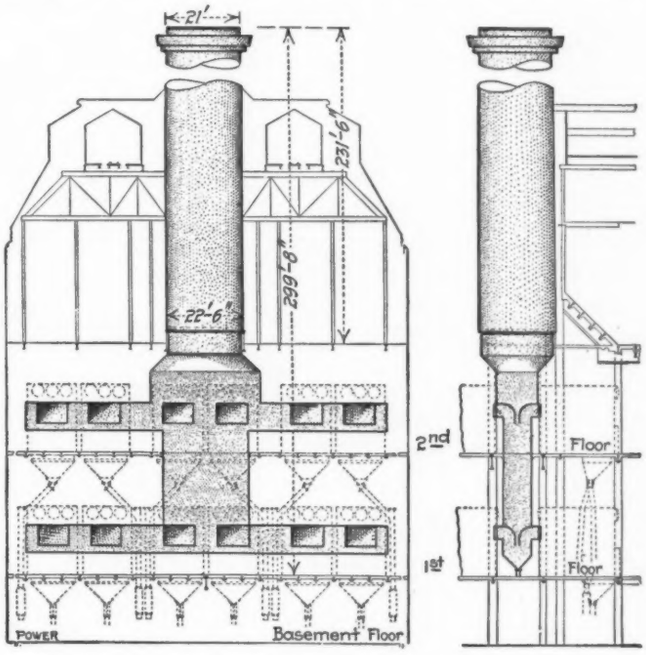


Fig. 5. Original Arrangement of Flues at Waterside Station

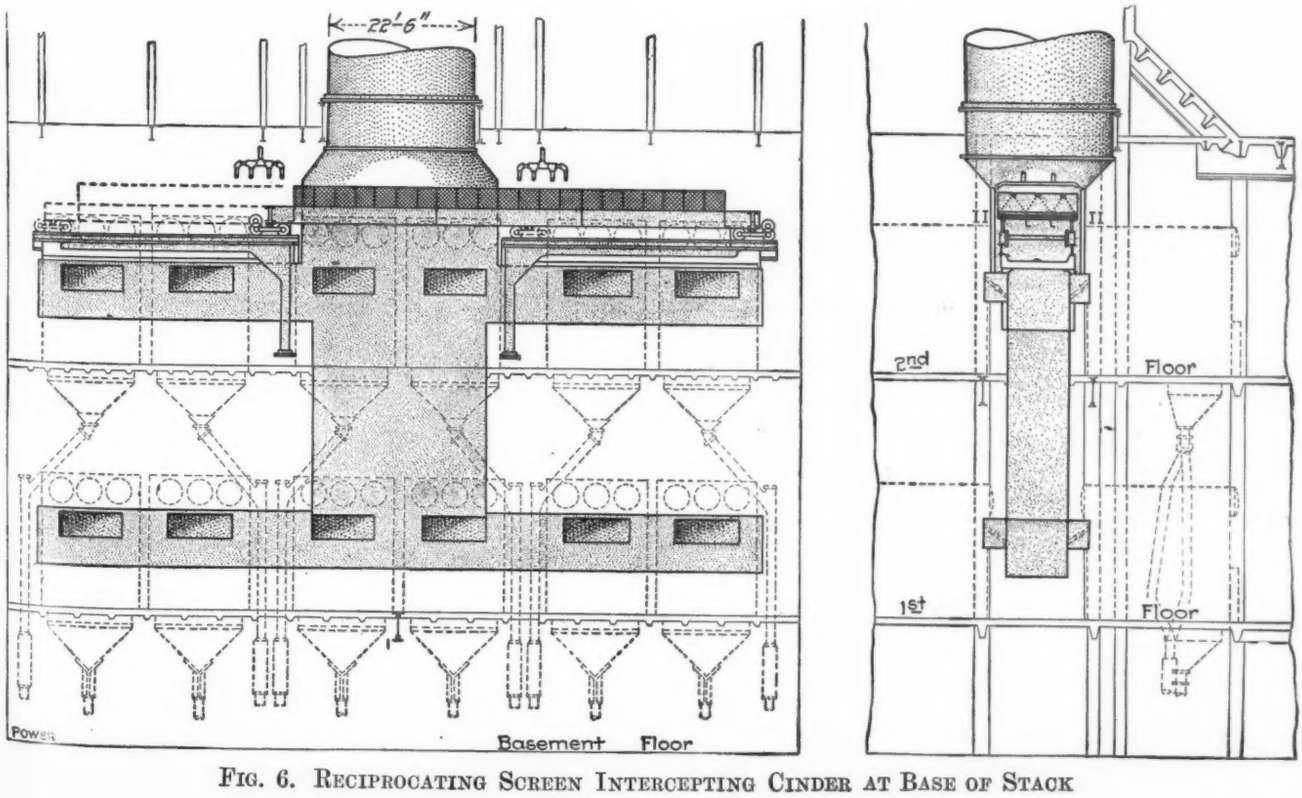


Fig. 6. Reciprocating Screen Intercepting Cinder at Base of Stack

cinder problem was a vital one to which ordinary methods and apparatus would not apply.

The original flues at Waterside No. 2 are shown in Fig. 5. The velocity of the gases through these flues was so high, that it could not precipitate the cinder, which was the original scheme planned.

Reciprocating Screen at Base of Stack

Before enlarging the flues, however, it was decided to try a large "sawtooth" screen of fine mesh, wider than the diameter of the base of the stack and over half as long as the flue. The reason for making it sawtooth fashion was to give it a much larger area than the base of the stack.

As shown in Fig. 6, this screen was mounted on wheels which ran on I-beams running parallel with the flue, the distance between the I-beams being slightly less than the width of the base of the stack. The stack was slotted so that this long screen could pass back and forth through it, thus intercepting the gases and catching the cinder before it reached the atmosphere. The general scheme is shown in the illustration.

At each side of the stack and above the screen was an air main containing air at 80 lb. pressure. The "drops" on this main were made to blow air into brushes which swept over the screen and removed the cinder from the mesh.

Beneath the I-beams over which the screen traveled was a concrete pit which received the cinder. As the cinder fell into this pit, water was run in, washing the cinder into pipes leading to the basement floor where the cinder was partly dried and disposed of.

This apparatus was discarded because when a screen of mesh fine enough to catch 50 per cent. of the cinder was used, the draft was seriously diminished and it was exceedingly difficult to clean the screen.

One would imagine that when nearly 50 per cent. of the cinder was trapped it would have stopped the complaints and convinced the company that it would not have to scrap apparatus costing thousands of dollars and experiment with other schemes. But there was further difficulty in this cinder problem, for as soon as a 25 or 50 per cent. gain was made in trapping the cinder, the new business (or load) so increased the coal consumption that the latter sometimes increased 25 per cent. while the cinder reduction also increased about 25 per cent. As the complainants got no relief, they kept up their protestations.

Softening Boiler Feed Water

By E. H. Robie

SYNOPSIS—A review of the principal systems, including boiler compounds, hot and cold processes, permutit and live steam purifiers; also the use of graphite and the luminator.

It is safe to say there are but few steam plants in this country using untreated water that are not troubled to some extent with scale or corrosion in the boilers. In this connection it might be noted that there is scale and scale. A New England engineer is apt to think that a deposit the thickness of a sheet of paper is bad indeed whereas the Middle Western engineer would be delighted if he could open his boilers and find only a quarter of an inch of scale on the tubes.

One is apt to get the impression that if only pure water were used, all troubles would vanish, but this does not necessarily follow as many people who have fed their boilers on water of condensation have found. Water that contains no mineral matter has been found to corrode iron in many cases. Just why it should do this is a disputed point, but the fact remains that it does, and as a result it is often an advantage to have a slight amount of mineral matter present.

Rain water as it leaves the clouds is pure. As it passes through the atmosphere it absorbs more or less carbonic-acid gas and air which it carries with it into the ground. As it seeps through the upper soil it will generally absorb still more carbonic-acid gas from the decaying animal and vegetable matter almost always present. Should the water fall on insoluble rocks, such as granite or marble, it will remain fairly pure. But if it passes through a layer of limestone, the carbonic-acid gas which it carries will cause it to dissolve away this rock, and as a result bicarbonate of lime will be present in the water. Should it pass through a layer of sulphate of lime or gypsum, the water will contain a large amount of this material.

It is generally known that the bicarbonates of lime and magnesia, when present in the water, form a comparatively soft scale; the sulphates of the same and also silica form a hard, flinty scale; the chlorides and nitrates are apt to cause corrosion; and the salts of soda and potash present, while not scale forming, are apt to cause foaming when sufficiently concentrated.

Boiler Compounds

The simplest, cheapest and most common method of softening boiler-feed water is by means of boiler compounds. Like other methods of softening, the boiler compound business has been largely put on a new basis in the last few years. Formerly, one compound was put on the market, which was supposed to be a cure for all ills. Nowadays the more progressive houses, first analyze the water and then prescribe. Often a stock of some three or four mixtures is kept on hand and that mixture used which is best fitted for the water. The basis of most of them is soda ash. Should the magnesium be high, caustic soda, lime or trisodium phosphate is often added. Sometimes paper pulp, waste from sugar houses and tanning factories or other organic matter is added.

Boiler compounds are fed in several different ways. The most rational is to have some arrangement whereby the feed is continuous and proportionate to the amount of water evaporated in the boiler. Often, however, a scoopful or a pailful is fed into the boiler all at once, a procedure certainly not to be recommended as it is liable to cause foaming, and besides an excess of medicine at one time will never make up for a lack of it during the

rest of the day when raw scale-forming water is going to the boiler.

Even if the compound is what it should be and is properly fed, the boiler is no place for chemical reactions to occur. A water that contains much scale-forming matter will have the latter precipitated as sludge, and if the boiler is overloaded this is liable to bake on the tubes and become hard. Also, a large amount of suspended matter floating about in the boiler is particularly conducive to foaming.

In waters containing not more than four or five grains of scale-forming matter, it may be advisable to use some reagent directly in the boiler, rather than go to the expense of installing treating and filtering tanks. In such cases there will probably not be enough matter thrown down in the boiler to give any bad results provided proper care is taken to blow down the boiler frequently.

Graphite

There is another class of substances closely allied to boiler compounds but whose action is mechanical rather than chemical. Perhaps the most important of these substances is graphite. When fed into the boiler this is supposed to adhere to the tubes, forming a smooth coating on which scale will not form. Advocates of this nonchemical process claim that anything strong enough to soften or remove scale will also attack the iron of the boiler.

Any chemist knows, however, that this is in error as reagents will attack sulphate or carbonate of lime which will not attack iron at all. For instance, a solution of soda ash, if fed into the boiler in proper amount and constantly, will in time soften the hardest scale, but the iron container in which the concentrated soda solution is kept will not be affected at all.

Cold Process System

The oldest commercial system of softening boiler feed water is known as the "cold process," in which the cold water is first treated with a solution of lime, either in the form of clear lime water or as milk of lime or cream of lime, which is much stronger. This is relied upon to precipitate the free carbonic-acid gas, the bicarbonate of lime and all of the magnesia present. The water is then treated with soda ash which precipitates all the remaining lime, which is in the form of sulphate, chloride or nitrate. The reason why these reactions take place may be simply stated as follows: If a chemical reaction takes place the general tendency is to form that product which is most insoluble. Take a water containing sulphate of lime, which is rather soluble, and add to it a solution of carbonate of soda—ordinary soda ash, and chloride of soda—ordinary salt. Now the lime could take three different forms. It could remain as the sulphate, or it could take the carbonate or chloride from the soda and become carbonate or chloride of lime. As has been already seen, sulphate of lime is readily soluble; chloride of lime is even more so, but carbonate of lime is almost insoluble, so this is what forms and it can be filtered out. All chemical methods of softening are based on this principle, of changing the lime and magnesia salts to an insoluble compound.

Sometimes the lime and soda are mixed together and added to the water all at once. What takes place is just the same, however, in the end. Also, for peculiar waters in which the impurities are proportioned in certain ways, caustic soda, barium hydrate and certain other chemicals are sometimes used. These are in general more expensive than the other chemicals.

It must be remembered that all substances are slightly soluble and the removal of every bit of the scale-forming matter cannot be obtained. It is almost impossible to get the carbonate of lime below two grains per gallon, and the hydrate of magnesia is also slightly soluble. Magnesia

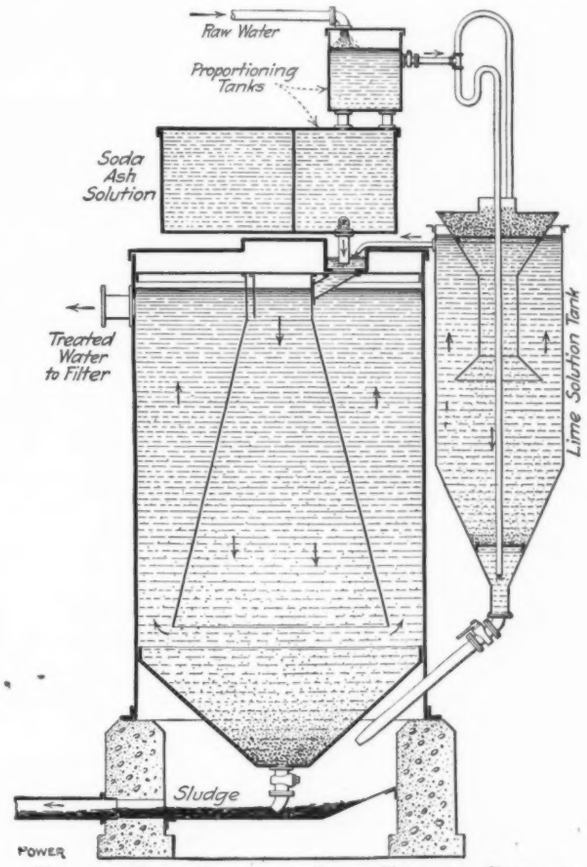


Fig. 1. Essentials of Cold Process System

is a much more difficult substance to remove than lime and as a result there is usually a small amount of this substance remaining in the water above its solubility. It will in general do no harm. Complete removal of the scale-forming matter, although it can be done, is an expensive process and the more of it taken out, the higher the expense. The engineer should not, therefore, look for complete absence of sludge in his boilers unless he is willing to pay the price. A small amount of sludge will generally do no harm. He is entitled, however, to expect absence of hard scale or corrosion in the boilers, and if any is present, the makers of the softening system in use should be consulted.

Cold-process systems possess certain disadvantages like most everything else. They are expensive in the first place, as large tanks must be erected for treating the water. A capacity of from one to three hours' supply should be provided, and more does no harm. The two chemicals used must be accurately proportioned, and with the somewhat complicated methods of testing often provided, a chemist is sometimes a necessity to tell just how much of the reagents to add. An excess of lime feed will form scale in the boiler just as if the lime was in the

water originally. Then, too, power of some kind must generally be used to stir up the water and chemicals, and in most systems to raise the chemicals up to the top of the treating tank.

Nevertheless, the writer believes the cold process, as described, to be the most dependable and in many other ways the best method to soften water when it is wanted cold. The degree of softening is good provided the apparatus is properly operated, and a correctly made system will not cause much trouble from clogging or any other sources. The savings gained from the use of softened water will in general amply repay for the installation of a good system.

Hot Process System

Another system in common use is the hot process. This is based on the fact that the temporary hardness of water is removed simply by heating, without further chemical treatment. Dissolved gases are also removed by heating the water to the boiling point, as they are only soluble in cold water. Lime is, therefore, in most cases, dispensed with in the hot process system, and only one chemical is ordinarily used, generally soda ash.

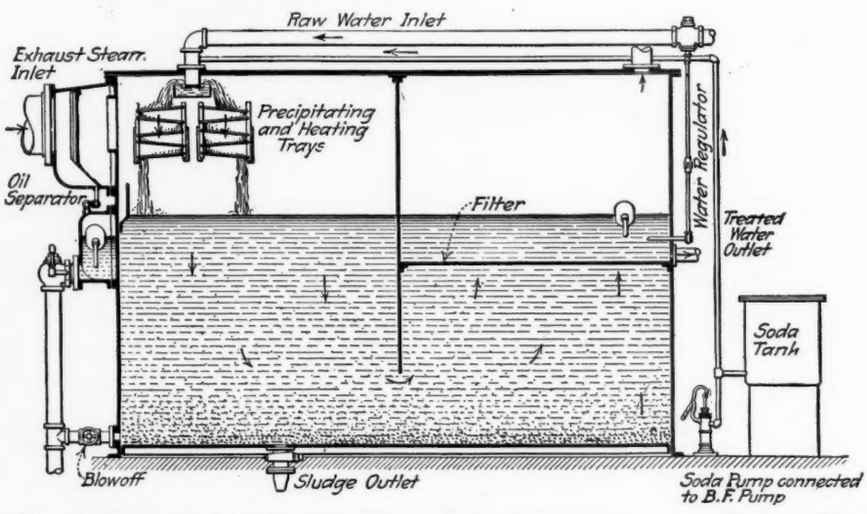


Fig. 2. Hot Process System Using Exhaust Steam

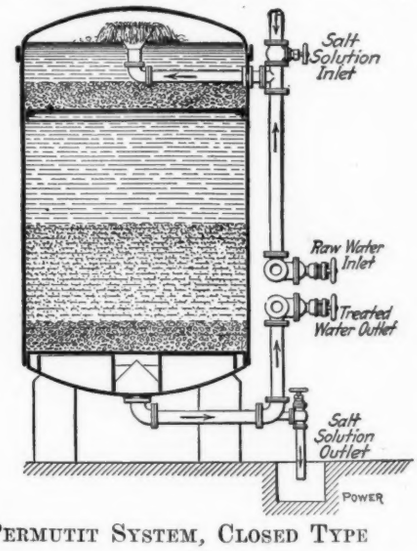


Fig. 3. The Permutit System, Closed Type

The water is first heated and this drives off the dissolved gases as already mentioned, which pass out of a vent at the top of the heater, or are carried off by the current of exhaust steam which is ordinarily the heating medium. Most of the carbonic-acid gas is driven off from the bicarbonates of lime and magnesia, and as the normal carbonate of lime is practically insoluble, most of it is precipitated here. Soda ash is then added to precipitate the balance of the lime and magnesia. With some waters of unusual character, another chemical is used in place of soda or in connection with it. Ordinarily this is not deemed necessary, however, as sufficient softening may be obtained with heat and soda alone.

Success of a softening system should never be based on the analysis of a treated water, but on the actual results in the boiler. It makes no difference to the practical engineer whether the treated water contains 100 grains of scale-forming matter per gallon, or 50 degrees of hardness, provided there is no hard scale in the boiler and there is no foaming or other trouble.

The chief disadvantage of the hot process is that when cold soft water is required, large cooling basins must be provided. For this reason when cold water is required it will in general be better to install a different process. Also, care must be taken to keep the temperature up within a few degrees of the boiling point, the nearer the better. If this is not done an excess of soda ash must be used, which not only adds to the expense of operation but is liable to cause trouble in the boiler. Another disadvantage, paradoxical as it may seem, is that the hot process system is sometimes considered such a simple thing that it gets no attention. It might be a good idea for some of the manufacturers to have some wheels turning on the outside so that the engineer would be reminded that it was there and needed a certain amount of attention, such as filling up the soda tank and occasionally cleaning the filter.

The system affords a considerable saving in first cost since the tanks are not nearly so large. A capacity of about 20 min. supply is ordinarily allowed to give plenty of time for reaction and settling of the precipitated matter, and the tanks are usually incorporated with an open feed-water heater and are, therefore, made of cast iron instead of wood. Each 10 deg. rise in temperature is believed to about double the velocity of reaction, and, therefore, not nearly as large capacity for reaction has to be provided as in the cold process. The engineer can easily check this up by taking a sample of his feed water in a glass and adding a little pinch of compound or soda ash to it. If the water is cold, the precipitate will not form until after long standing, but if it is hot, the impurities will be thrown down almost instantly. This process also affords a saving in chemicals, inasmuch as lime is not required, its work being done by exhaust steam which would probably go to waste. Even if live steam is required, the water goes to the boiler hot instead of cold. Even if a slight excess of soda is added no harm will be done, whereas an excess of lime will likely form scale.

Live-Steam Purifiers

These are not used to any great extent and will only be taken up briefly. They rely on principles already stated for their operation. The purification tanks are under pressure, and the temperature of the water is considerably above the atmospheric boiling point, due to the injection of live steam. The high temperature breaks up the bicarbonates of lime and magnesia more completely

than the heat in an ordinary hot process system. The sulphates, chlorides, etc., are not precipitated to any great extent, however, and this "permanent hardness" passes over into the boiler where it will form scale unless the water is further treated.

Permutit Process

The "Permutit" process of softening water is very little used in this country, although it has found considerable favor in Europe. Its discovery was comparatively recent. In this method the water is passed through a layer of an artificial zeolite—a complex silicate. The lime and magnesia in the water unite with the zeolite, the trade name of which is Permutit, and their place is taken by sodium salts. In this process, unlike the preceding ones, absolutely all of the scale-forming matter may be removed and the hardness can thus be reduced to zero. The working of the Permutit is absolutely automatic, but it must be regenerated at intervals of about 12 hr. by passing a concentrated solution of ordinary salt through the material. Double units must, therefore, be provided where the plant runs night and day. The filtering and treating apparatus varies in size from 1 ft. in diameter by 5 ft. high to 10 ft. in diameter by 12 ft. high.

A disadvantage of Permutit is that, although the hardness of the water may be reduced to zero, the total solids are not reduced at all as in other systems. The bicarbonates of lime and magnesia are transformed into bicarbonate of soda, and in water containing a large amount of temporary hardness the treated water is, therefore, very alkaline. The original cost of the Permutit is rather high, but there is little deterioration. The water flowing to the filter must be free from mechanical impurities and the temperature should not be over 100 deg. The field of Permutit would appear to be limited to cases where an alkaline water is desired or, at least, is not detrimental.

The Luminator

About the only other process used at all commercially is known as the "Luminator." In this process the cold raw water is allowed to run over aluminum plates before being fed into the boiler. Just what effect this aluminum treatment has on the water is unknown, but it is claimed to prevent the formation of scale. No scale-forming matter is removed before the water passes into the boilers and the Luminator should, therefore, be really classed in the boiler-compound group. It has been introduced only slightly in this country.

This completes the list of various methods of water softening. It is a subject on which much work has been done and there is really little excuse for hard scale formation in any steam boiler. Various tables have from time to time been published, showing the decrease in efficiency due to the presence of scale and the ordinary engineer can easily figure out just how much this troublesome stuff is costing in dollars and cents. Furthermore, there is also an added loss, due to the cost of cleaning, the decreased life of the boiler occasioned thereby, and the cost of repairs, such as tube and cap renewals. Almost any manufacturer of a softening system will be willing to guarantee a maximum cost of treatment, and by adding, say, 10 to 15 per cent. of the cost of the system to this to cover interest and depreciation, the saving due to the use of soft water may be easily reckoned.

Recent Court Decisions

Digested by A. L. H. STREET

Liability of City Operating Electric Plant—Although a city is not liable for negligence of its officers or employees while exercising strictly governmental functions, where it undertakes to furnish electric current to private consumers for profit, it becomes liable for injury to person or property resulting from negligence of its employees in stringing wires to be used for such commercial purposes. (New Jersey Court of Errors and Appeals, Karpinski vs. Borough of South River, 88 "Atlantic Reporter" 1073.)

Classification of Fuel Gas Rates—Under an ordinance prescribing different rates for fuel gas, according to whether it is used for "domestic consumption," "public institutions" or "manufacturers," a person who conducts an automobile garage, in which he uses a gas engine for the purpose of generating electricity to be used in his business, is entitled to the rate prescribed for manufacturers. (Louisiana Supreme Court, Henderson vs. Shreveport Gas, Electric Light & Power Co., 63 "Southern Reporter" 616.)

Effect of Contract to Supply Power—A mining company is bound by a contract, made by a person from whom property was taken over in exchange for one-third of the company's stock, to receive electric power for a period of three years, where the company continued to receive power in recognition of the contract for some time, although such person had not been elected a director and general manager of the company when he made the contract. (Kansas Supreme Court, Empire District Electric Co. vs. Eureka Mining Co., 136 "Pacific Reporter" 924.)

Assumption of Risk by Engineer—An experienced stationary engineer assumes the risk of being injured on account of the existence of such defective conditions surrounding the engine as narrowness of a space between the base on which the engine rests and the wheel pit, absence of adequate railing along the pit, and slipperiness of the floor caused by oil dropped by himself on the floor, especially where he has been in charge of the machinery for several days and, hence, is thoroughly acquainted with such conditions. (Texas Supreme Court, Snipes vs. Bomar Cotton Oil Co., 161 "Southwestern Reporter" 1.)

Rights of Way over Public Lands for Power Purposes—The act of Congress of July 26, 1866, confirming rights of way over public lands belonging to the United States, for the purpose of constructing ditches, etc., for the transportation of water for mining, agricultural, manufacturing or other purposes, granted rights of way for ditches and canals for the generation of electric power; generation of electricity being a beneficial use for which an appropriation of water might be had. (United States District Court, District of Utah; United States vs. Utah Power & Light Co.; 208 "Federal Reporter" 821.) The court further holds that defendant company, having obtained a right of way over public lands for a pipe line to conduct water for power purposes, the right was not affected by subsequent incorporation of the lands in a forest reserve. In his opinion in this case, Judge Marshall says: "I am satisfied that the defendant has title to a right of way for its pipe lines and reservoir under section 9 of the act of July 26, 1866, and was under no obligation to proceed under the subsequent legislation. But having elected to stand on the grant of section 9 and the amendment thereto including reservoirs, it cannot claim any additional right under this subsequent legislation."

Duty to Provide Safeguards in Engine Rooms—The owner of a power plant is liable for injury to a person directed to go into the engine room to "shut down the engine," if the accident is directly attributable to failure to provide a railing on a stairway leading to the room, or to failure to guard the machinery, although the person may not have been an employee at the plant, according to a recent decision of the Minnesota Supreme Court, in the case of Mitton vs. Cargill Elevator Co. (144 "Northwestern Reporter.") The court declined to determine whether the Minnesota statute which requires machinery, etc., in factories to be guarded was intended for the protection of persons other than employees; holding that liability for failure to discharge this duty exists in favor of any person who is requested to perform such service, whether he be an employee or not. In this case it appeared that the stairway consisted of eight steps, descending 6 ft. in a lateral distance of 3 ft. 9 in.; and that a flywheel and cog-wheels located near the foot of the stairway were not safeguarded. The man who went to the engine-room, having been fatally injured, it is not known whether the accident resulted from the lack of railing on the stairway, or want of guard on the machinery, but the court finds that the injury was caused by one of these elements.

Operating Characteristics of Centrifugal Pumps

By A. B. Morrison, Jr.

SYNOPSIS—From the operating standpoint rather than that of design. The effect of speed and head on the capacity and the influence of throttling the discharge vs. some form of speed control.

While centrifugal pumps are in general use in nearly all lines of work there is still, among many engineers, a lack of knowledge as to what their performance will be under anything but the conditions for which they happen to be installed. The man who has to operate the pump or is responsible for its operation is not particularly concerned with the reasons which prompted the designer to use an impeller with certain dimensions or with a certain blade angle, but he is interested in the effect which certain variables, such as speed and head against which the pump is to work, will have on the capacity if he wants to use the pump in some other location.

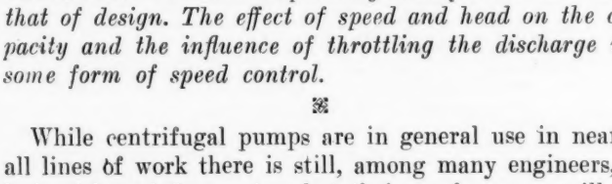


Fig. 1. Quantity-Head Curves of Centrifugal Pump

He knows the centrifugal is not a positive pump but he is not able, usually, to forecast with any degree of accuracy how fast he ought to run the pump under new conditions to do certain work. It is generally stated that with a centrifugal pump the capacity varies as the speed, the head generated by the pump as the square of the speed, and the power required to drive the pump as the cube of the speed. While this is true theoretically of the pump and also under certain operating conditions, it does not mean, as is sometimes supposed, that to get an increase, for example, of 5 per cent. the pump should be speeded up 5 per cent, since the capacity discharged, as will be shown later, depends on certain characteristics of the system to which the pump is connected.

It is also desirable to know what effect throttling the discharge will have on the efficiency of the pump and whether it is better to use, where feasible, some form of speed control in preference to throttling. For these reasons, the writer believes that an article dealing with some of the more important characteristics of this type of pump, considered from the operating and not the design standpoint, will be of interest to many readers of Power.

It is absolutely essential, in investigating the behavior of a centrifugal pump in operation, to know the head curve of the system to which the pump is to be connected and for that reason the head curve of the system will be considered before attempting to do anything with the centrifugal-pump curves proper. The head, which includes both suction and discharge, against which the pump works may be any one of three distinct classes: (1) Head entirely static; (2) head entirely friction; (3) head part static and part friction.

The first case seldom occurs in practice. If the pump were under a constant suction head, without any connecting piping, and the outlet of the pump were connected, without any piping, direct to a large standpipe of such size that practically no friction existed in it and in which the water, due to an overflow pipe, were at constant level, we would have the first case. In this instance, the head curve would be a straight horizontal line. Under similar conditions, no piping on suction or discharge, but with the standpipe gradually filling, the head curves would be represented by a series of horizontal lines taken at whatever distances apart were felt advisable to get the data required as to speed, capacity, etc., on the pump.

The second case mentioned is not common, either, but occurs more frequently than the first. It would be represented in practice by a level pipe with the suction and the discharge at the same level. The head curve under such conditions is shown in curve *E*, Fig. 1. In laying out such a curve the friction head at the rating of the pump, which we will call 100 per cent., is obtained from friction tables, showing the loss in head at the rated capacity of the pump through the size of pipe used. This gives one point on the curve, the capacity being represented always by abscissas (horizontal scale), and the head by ordinates (vertical scale). The friction head varies as the square of the velocity which, with a given pipe, is equivalent to the square of the quantity discharged. The following table shows the friction heads at less than rating, all quantities being in percentage of those at rating:

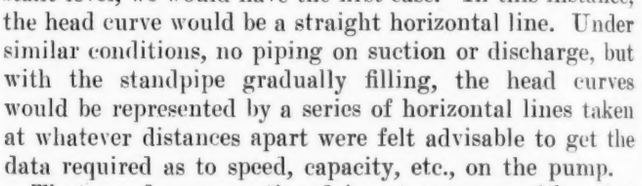


Fig. 2. Characteristic Curves of a Centrifugal Pump

Capacity in per cent....	90	80	70	60	50	40	30	20	10
Head in per cent.....	81	64	49	36	25	16	9	4	1

The third case is the one which almost invariably occurs. In laying out this curve the ordinate at zero discharge is the actual elevation through which the liquid is to be raised. At any other rate of discharge the friction in the pipe, based on the quantity of water flowing, is computed and the ordinate at this discharge is the static head plus the friction head. The general form of this curve is shown in curve *A*, Fig. 1, where it is assumed

the head is based on 20 ft. of friction at the normal discharge (1000 gal.) of the pump. At any other point the friction head is computed from tables or can be readily ascertained in terms of the friction head at rating by using the table just given. At 125 per cent. of rating the friction head is 156¼ per cent. greater than at normal and at 150 per cent. of rating is 225 per cent. more than at normal, or based on 20 ft. of friction head at normal capacity these quantities are 31.25 ft. and 45 ft., respectively, to be added to the static head to secure the total head.

The characteristic curves of a centrifugal pump, as shown in Fig. 2, are more or less familiar to all engineers. While these curves differ for various makes and types, their general form is characteristic of all centrifugals. They are plotted for constant speed. One important fact to be noticed is that the head given by the pump depends entirely on the amount of liquid being pumped; or, to state it the other way around, the pump will discharge against a given head only a certain amount of water. The only way in which the head developed by the pump for a given discharge can be increased is by speeding it up. The discharge, as will be noticed, can be entirely closed without harming the pump.

In Fig. 1 the quantity-head curve of the given pump is shown together with the head curve of the system, both in heavy lines. For ease of computation the capacity at normal rating is taken as 1000 gal. per min. and the total head as 100 ft., composed of 80 ft. static and 20 ft. friction. Suppose, however, that it is desired to move the pump to a new location in which the static head is increased to 100 ft., the friction head at rating remaining unchanged, giving a total head of 120 ft., and it is desired to have the pump discharge the same amount as formerly, the new head curve B is obtained. Since the interception of the quantity-head curve of the pump with the head curve of the system gives the quantity of water which the pump will discharge it is evident that at the original pump speed only 76 per cent. of normal discharge will take place. To determine the new speed at which the pump must operate to give the head of 120 ft. necessary to discharge 1000 gal. per min., the pressure given by the pump is taken as proportional to the speed at which it operates. This is approximately true and close enough for all practical purposes. The relation then holds

100 (*head at normal speed*) : 120 (*head required*) : : *given revolutions squared* : *required revolutions squared*

Hence the required r.p.m. equals 109.5 per cent. of the original r.p.m., or the pump should be speeded up practically 10 per cent., to meet the new conditions and discharge practically the same amount of water as at first. The new quantity-head curve of the pump at approximately 10 per cent. increase in speed is shown by the dotted curve B_1 in Fig. 1. It has the same general form as the original.

If it is assumed that the static head on the pump is decreased to 60 ft., the friction head remaining the same, and the total head being 80 ft. in place of 100 ft., the new condition can be met in two ways. To meet the new head conditions by changing the speed of the pump, the former should be reduced in the proportion $\sqrt{100} : \sqrt{80}$, or to approximately 90 per cent. of normal at which the quantity-head curve at rating will exactly balance the computed head curve of the system and the pump will discharge its normal quantity of liquid. Curve C, Fig. 1, shows this curve of the pump at the reduced speed.

It is apparent, however, that this new condition can also be met by allowing the pump to operate at normal speed and by throttling the discharge so that only the head necessary to force 1000 gal. per min. through the system will be available, the rest being wasted in friction in the throttle valve. A comparison of these two methods will be taken up in detail later.

There is a further interesting fact brought out by these curves. It has been mentioned that the quantity discharged by a centrifugal pump is proportional to the speed, and that this is sometimes thought to mean that for a certain increase in speed the amount discharged is proportional to such increase. In Fig. 1, however, curve E is a head curve corresponding to the first case, viz., entirely static; curve D corresponds to the second case, entirely friction; and curve A is the third case. Taking curve E where the head is constant for all capacities, an increase in speed of approximately 10 per cent. produces an increase of 21 per cent. in the quantity discharged. For curve D the quantity discharged at 10 per cent. above normal speed is 10 per cent. more than normal or the increase is exactly proportional to the speed, and this is the only case where the relation holds.

In curve A, where the head is partly static and partly friction, an increase in speed of approximately 10 per cent. produces an increase in the volume discharged of 15 per cent. Furthermore, the only case where the head on a pump for a given discharge is exactly proportional to the square of the speed and the discharge is proportional to the speed is for the second case where the head is entirely friction. Hence, as stated earlier, the capacity discharged by the pump and consequently the head depend entirely on the head of the system against which the pump works.

So far, only the speed necessary to obtain a certain discharge under new conditions has been considered and no investigation made of the efficiency of the pump nor the power required to operate it. Unless this be known, there is the possibility of the motor or shafting being overloaded.

An approximate method for obtaining this horsepower, and one which is accurate enough for ordinary calculations, is as follows: The quantity in gallons per minute discharged at the new speed is divided by the new speed taken in percentage of normal. From the brake horsepower curve in Fig. 2 the horsepower corresponding to this quantity just obtained is found and this brake horsepower is multiplied by the cube of the new speed expressed in percentage of normal speed. The result is the brake horsepower required at the new speed. Applying this rule to the results shown by the curves in Fig. 1, the following results are obtained:

For curve B, 10 per cent. speed increase: Gallons discharged per minute, 1000; new speed in per cent. of normal, 110; $1000 \div 1.10 = 909$; b.hp. for 910 gal. per min. (Fig. 2), 37; $1.10^3 = 1.331$; $37 \times 1.331 = 49.25$ b.hp. required at 1000 gal. per min. and 120-ft. head.

B.hp. at 1000 gal. per min. and 100-ft. head (normal rating) = 38.5.

Increase 128 per cent., which is slightly less than the cube of the speed.

Applying the same methods to curve C, showing 10 per cent. decrease in speed, the b.hp. required is 29.2, or

about 76 per cent. of that required at normal, slightly more than if the power required were proportional to the cube of the reduced speed compared to the cube of the normal speed.

It has been seen that at the reduced head the pump can be run at normal speed by throttling the discharge until just the proper amount of water flows. In this case, though, the brake horsepower required is the same as when discharging the same quantity at the higher head, since the pump generates this higher head at the given speed and capacity. The net efficiency when throttled is the efficiency at the normal rating multiplied by the ratio between the head actually required and the normal pump head generated. Referring to Fig. 2, when pumping 1000 gal. per min. the pump generates a head of 100 ft. and the efficiency is 65 per cent. The head actually required by the system, as shown in curve *C*, Fig. 1, is 80 ft. Hence, the net efficiency of the pump at normal speed when throttled to 80-ft. head is

$$0.65 \times \frac{80}{100} = 52 \textit{ per cent.}$$

As a check on this result the brake horsepower required at normal speed pumping 1000 gal. per min., as given by Fig. 2, is 38.5. The water horsepower required at 1000 gal. per min. and 80-ft. head is

$$\frac{1000 \times 80 \times 8.33}{33{,}000} = 20.2$$

Hence the efficiency

$$\frac{\textit{water horsepower}}{\textit{brake horsepower}} = \frac{20.2}{38.5} = 52 \textit{ per cent.}$$

as just given.

With a variable-speed direct-current motor the proposition of securing the correct speed for any given set of conditions is easy and the motor efficiency and the overall efficiency of the equipment are unimpaired. Where it is necessary, however, in order to get any change in speed, to use resistance in series with the rotor, it is interesting to compare the combined efficiency of the pump and the motor obtained by this method with that obtained by throttling alone. Referring again to Fig. 1, the speed required at the reduced head, curve *C*, at 1000 gal. per min. is approximately 90 per cent. of normal. The horsepower calculated above for this discharge at 90 per cent. of normal revolutions is 29.2. In the case of a motor with resistance in series with the rotor, the efficiency at any reduced speed compared to that at normal speed with no resistance in the circuit is closely proportional to the revolutions at reduced speed compared with normal revolutions, so that reducing the speed to 90 per cent. of normal the efficiency is reduced correspondingly. In other words, at the reduced head

$$\frac{29.2}{0.90} = 32.4 \textit{ b.hp.}$$

is required when resistance in series with the rotor is used.

Tabulating the results, the following comparison based on reducing head to 80 ft., as shown by curve *C* in Fig. 1, is obtained. Each percentage gives the per cent. of brake horsepower required at rating:

B.hp. required by rotor control.....32.4 = 84.4%
B.hp. required by field control on motor.....29.2 = 75.8%
B.hp. required by throttling discharge.....38.5 = 100%

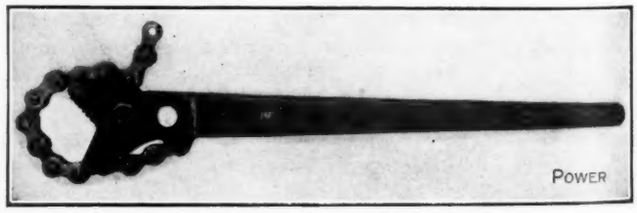
In other words, by using resistance in series with the rotor there is a saving of 6.1 b.hp., or 15.8 per cent., over throttling, and by using some form of variable-speed direct-current motor the saving is 9.3 b.hp., or 24.2 per cent. It is evident that where the head is likely to be less than normal for considerable periods and where the cost of power is important, some form of speed control is necessary. The variable-speed direct-current motor, as shown, is by far the best proposition. Armature control is sometimes used, but not often, as usually a variation of 10 per cent. or, at the most, 15, will take care of most installations and that can usually be obtained from any standard shunt-wound motor. With alternating-current motors, throttling is generally resorted to, owing to the special character of alternating-current variable-speed motors unless the installation is of fairly large size.

In working out curves for any given pump, the results obtained at various heads and rates of discharge will depend entirely on the characteristics of the particular pump and these may differ decidedly from the one used here as an illustration. If the pump has a steeper characteristic—i.e., if the head falls off more rapidly as the discharge increases—than the one shown, the difference in volume for any given change in speed will be less than for the curve given, whereas, with a flatter characteristic the change in volume for a given change in speed will be greater. With a flat characteristic, the head against which the pump works must be closely calculated in order to run the pump at the proper speed.

Wherever feasible, and especially if the pump is of large size, the writer wishes to emphasize the fact again, that some form of speed control should be used. It is almost impossible to determine accurately beforehand the head against which the pump will work, and with a fixed speed any change in piping or operating conditions may make a great difference in the amount discharged and in the power required.

Gealy Chain Pipe Wrench

The principal points of construction of the Gealy wrench are found in the drop-forged steel handle and jaws, the teeth of which are tempered. The chain is of flat links, and can be had in special lengths if desired.



GEALY CHAIN PIPE WRENCH

The wrench operates on the cam-lever principle; the handle serves as a cam lever and the jaws as a cam thrust. A slot in the jaws allows the handle bolt to move freely with the action of the handle as a cam lever, therefore, there is no strain on the bolt when the jaws grip. The cam thrust forces the jaws forward, thus getting a firm grip on the pipe.

Releasing the cam lever from the gripping position loosens the grip of the chain and allows the wrench to be moved around on the pipe or removed from it.

The manufacturer, the Gealy Wrench & Manufacturing Co., Grove City, Penn., claims that this wrench has a positive grip and that it will not crush the pipe.

Editorials

Keeping Piping Costs

On account of the multiplicity of detail involved, accurate estimates of the cost of power-plant piping, at present are difficult to obtain in advance of construction. Here is where the engineer who is fond of compiling data can do a useful service tending to put this branch of power-plant work on a more scientific basis. Even though the total cost of piping, in most stations, is a small part of the whole installation expense, reliable figures on this subject are desirable, since every class of equipment which can be reduced to reasonably accurate estimates facilitates the larger mastery of the work by the station designer and by operating men required to figure the probable cost of new or remodeled equipment.

The important items in piping cost are obviously susceptible to labor and material classification. The kind of pipe employed for each class of service, its size and length, with the number of fittings involved; the material cost as delivered on the job, and the number, time and wages of fitters should not be unduly difficult to tabulate if the engineer can give a little attention to the task. Live steam, exhaust, feed-water and other piping systems are fortunately easily distinguished and are radically different in their bills of material. The chief difficulty comes in separating piping costs from installation expenses in connection with auxiliary apparatus which such piping serves in plants where the contractor puts in the entire equipment for which he is responsible with a force of erectors whose labor is not sufficiently separated by the timekeeper to permit the engineering classification desired.

The piping layouts in different plants must be compared in numerous ways in getting together material suitable for future estimates. Perhaps the most natural basis is the piping cost per kilowatt of plant capacity for each main and auxiliary system installed, including the labor and material classification, where this can be made, but, in any case, including the bill of material and, when possible, an estimate of the amount of time and its cost as required by the erecting force. This unit of comparison would apply to live-steam and exhaust piping, while an appropriate basis for feed-water piping might be the cost per boiler horsepower, for lubricating-system piping the cost per gallon of capacity, for air-compressor piping, the cost per foot of the dominating pipe size, for circulating-water piping the cost per foot per gallon per minute delivered, and so on. Sometimes an estimate of the total weight of piping and fittings involved may be desirable and the cost to a per-pound basis, including the expression of the weight of material required for plants of stated capacity.

In figuring new relatively simple work a bill of material should be prepared first, after which its approximate cost delivered can be determined by referring to similar material bills as classified by the engineer and checked, when possible, by quotations from piping-supply houses. If some effort has been made to tabulate the main items of cost, the engineer will find himself better able to judge bids and estimate forthcoming expenses. Where very many valves, tees, elbows and other fittings are needed, the total material cost per unit of capacity will doubtless be necessary, with a supplementary note as to the number of principal fittings required.

The space required to install the smaller sizes of pipe ordinarily does not complicate the question much from the point of view of installation labor. The larger piping space requirements depend considerably on the capacity of the generating units and auxiliary condensing apparatus; hence costs per kilowatt of capacity served are helpful.

Common sense should be applied when compiling and analyzing piping-cost data. Excessive subdivisions of such expense are of no advantage in dealing with very small installations, but the fact that piping estimates for the same job seldom vary 50 per cent., indicates that more attention to the subject is warranted than has been accorded it in the past.

Concerning the Study Course

This week's installment of the Study Course concludes the lessons on trigonometry. These lessons have covered the fundamentals of the subject sufficiently to make possible the solution of any triangle, and the student should make himself thoroughly familiar with this much of the subject at least so that he may proceed intelligently with the course on mechanics to come later. Not that mechanics involves much trigonometry, but in the occasional problems where the latter is needed, it is indispensable.

For this reason it will be well for those following the course not to be content with solving only the five problems given with each lesson, but to make up for themselves others similar to those demonstrated, and more difficult ones, until they can do any problem involving the sides, angles and areas of either right or oblique triangles that is capable of solution. Preferably, examples should be made up and worked out that relate to the engineer's work in or about the plant. It will be surprising how many bits of useful information can be gained in this way concerning the plant or its apparatus that were otherwise unknown or at best learned less exactly by makeshift approximations. While the applications of trigonometry may seem few and of little importance at first, many will appear later when the study of mechanics is taken up.

It was the intention to follow the trigonometry section directly with the one on mechanics, but requests that two other matters be covered in the course, have led to the decision that they be introduced at this time. First will be given an explanation of the slide rule and its use, for it is a very handy tool to the engineer. Many are already using it and those that are not can hardly afford to remain in ignorance of its value. Especially is this true when the handling of it is so simple and pro-

ficiency so easily acquired. To see one used for the first time gives the impression that it is a mysterious instrument, but, once this false fear of it is overcome, with a little patience, all of its tricks can be learned. Then it is found to be surprisingly simple, and one wonders he has so long done without it. To use a common expression in advertising, "once used, always used," for probably no one who ever became acquainted with the slide rule was ever thereafter without one. Rules can be had now in such inexpensive forms that there really is no excuse for not owning one.

The other subject that has been called for is curve plotting. This, too, is extremely useful and likely also to be familiar to many who are following the course. It will do no harm, however, for them to have a little review of it and some who use it now to only a limited extent may get new ideas of its possibilities. No attempt will be made to exhaust this subject, nor to go into many of the more intricate forms, but only the simpler and most useful applications will be treated. As a check on mathematical calculations, curve plotting is of considerable service, but as a means of graphically presenting facts that may be clouded in a mass of figures, it is principally of value. In many of their forms, curves take the place of tables, giving quick means of obtaining values, and in other forms, as of plotted observations or other data, they show at a glance the law of variation and indicate what may be expected under other conditions in advance of their investigation.

Certainly the few lessons on the slide rule and curve plotting will be warranted for themselves alone and it is likely that they will be of no little advantage in connection with the mechanics course then to follow.

Conditions in the South

What is to become of the isolated power plants of the South? How soon will the hydro-electric central stations displace them with electrical energy developed from the many available water powers with which that section abounds?

Until recently, the power utilized in cotton mills and other factories was produced by comparatively small steam plants, except in the larger cities, where the steam central station had gained a permanent foothold. The small mill plant gave employment to firemen, oilers and engineers, and furnished a market for all kinds of power-plant apparatus. Now these men are being forced to look for other positions, because their steam plants are shutting down and hydro-electric power substituted. The market for small power-plant apparatus is becoming limited because comparatively few new steam plants are constructed.

It is predicted that within a few years in certain parts of the South the isolated plant will have been eliminated. The systems of electrical transmission which have been perfected make this prediction not only possible but probable. With the present facilities, electrical energy is being transmitted two hundred miles at high voltages, and then stepped down to voltages to suit the purchaser's requirements.

That there may be no interruption in service, most hydro-electric companies obtain control of steam central stations at various points on the transmission line and keep them for stand-by service, ready to be started if the water-power plants have trouble.

Arguments bringing out the reliability of hydro-electric service and the precautions taken against failure of electrical energy are attractive to the mill operator who has seen his production fall off, because of his own power-plant troubles. The promise of electrical energy at lower cost than when developed in the isolated plant is also an incentive to make a change.

Apparently, nearly all new cotton mills being built in the South will be operated by energy from hydro-electric stations. The chance of powering a new mill with an electrical steam plant is remote. The necessity of sustaining the initial cost of a power plant is eliminated and the absence of firemen, oilers and engineers on the payroll is attractive to the manufacturer.

Old established cotton mills will give a short respite to the power-plant operator. The hydro-electric plant has displaced but few of them, because it would mean discarding the steam apparatus and installing electric motors to drive the machinery. The cost would exceed what little, if any, saving was made by the change.

Power-plant owners do not seem to grasp their opportunities, nor do they learn by the experience and example of others regarding power-plant practice. After the engine is old and worn the steam consumption is excessive, requiring more boiler capacity and fuel. The power plants contain the ordinary equipment and no more and are practically left to take care of themselves.

The central-station manager aims to purchase fuel and supplies economically and provide instruments to ascertain if the best economy is being obtained; whereas the isolated-plant owner does neither, and then wonders why the power cost is excessive. The experiences of others who make a business of power for commercial use mean nothing to him.

Ignorance is the cause of most excessive power-plant costs. For instance, more power is needed to operate the machinery in the new part of the mill. Somebody decides the only thing is to install more boilers and a new engine, which usually requires an addition to the boiler and engine buildings and more help. This additional power becomes a burden from the beginning.

The man responsible for the new power-plant apparatus is not aware that, by adding a single generating unit and condenser outfit, the output of the old steam plant can be almost doubled without additional boilers or without additional boiler-room help.

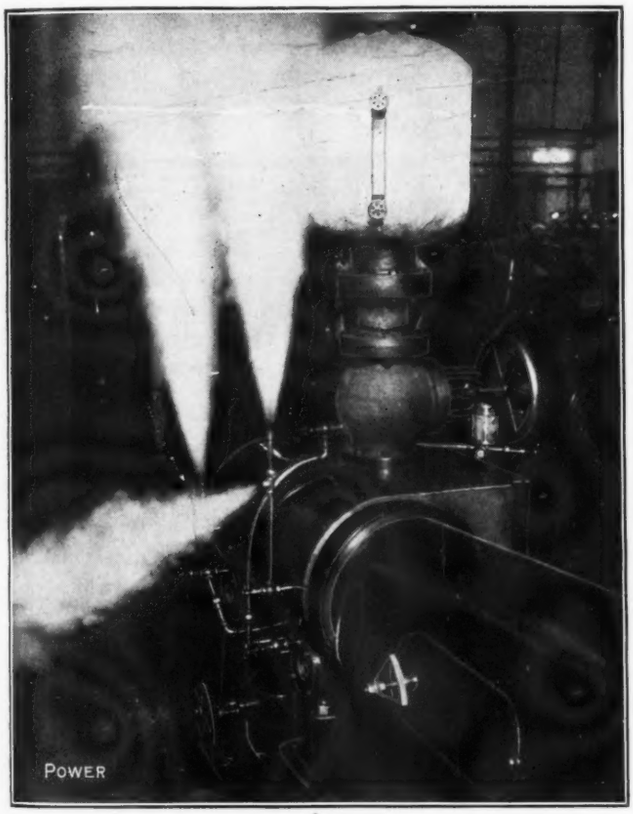
A mixed-pressure turbine to operate with the exhaust steam of the old reciprocating engine is not considered, probably because their economy in combination is not known, and yet, such a unit requires small floor space, does not draw an ounce of steam from the boilers, is operated by the engineer already in the plant and adds as high as ninety per cent. to the plant-load capacity, using the same amount of steam in the reciprocating engine as before.

Engineers should become familiar with the advantage of the mixed-pressure turbine and its value as a power producer in plants already established. There are instances where they would not be adaptable under some operating conditions, but in such plants the engineer must figure on other means for developing power cheaper than it can be purchased from the steam or hydro-electric central station. If they do not and cannot do this, there is every reason to believe that the operating days of their steam plants are numbered.

Correspondence

A "Tight" Engine That Leaked

We are sometimes mistaken about the condition of our engines. Recently I asked an engineer how the valve of his engine was holding—i.e., if it was steam-tight—and he replied that it was. The engine was running smoothly,



Evidence of Leaky Valve

as a badly leaking engine will at high speeds.

I suggested that we test the valve for leakage. He placed the valve in its central position and opened the indicator-pipe connections and closed the valve in the exhaust line. On opening the throttle valve, the steam from the indicator-connection openings reached the ceiling as shown in the photograph.

He was a surprised engineer when the steam started to blow through the connections.

C. R. McGahey.

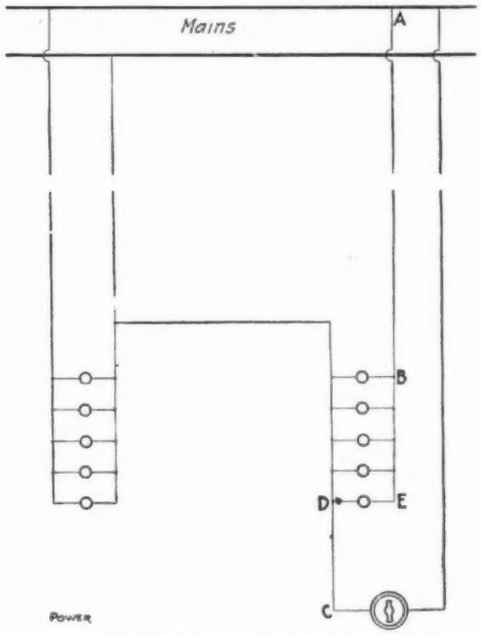
Baltimore, Md.

A Paradoxical Switch Connection

Calling on one of my engineer friends one day I found him in trouble. He had installed some new wiring that had to be in service that evening and it refused to work because the fuses would blow when he opened the switch. At first it appeared like a case of a short-circuit in the switch. Accordingly I disconnected and dissected the switch, but found nothing wrong, outside of the contacts being slightly burned. I then went to the fuse cabinet and, opening the main switch, replaced the blown fuses

There were two or three other circuits on this main switch besides the one having the paradoxical switch. This I had left disconnected, leaving the circuit open. Now, if my friend's theory were correct the fuses should blow as soon as the main switch had been closed, but this did not happen.

A new problem now arose: The lights on the open circuit which should have been out were burning. The trouble was evidently not in the switch, so I next gave my attention to the wiring, which was something of a Chinese



Original Switch Connections

puzzle, because in trying to economize on wire the engineer had made a number of combinations. The wires were run in molding; there were several branches and all on the main switch in the fuse cabinet with the exception of the one circuit, causing the trouble. This had a separate switch so that the lights in this circuit, which lighted a private office, could be cut out without interfering with the other circuits, which lighted the adjoining stock room. I finally made a sketch of the circuits and after eliminating the nonessentials found that they had been connected as shown in the diagram.

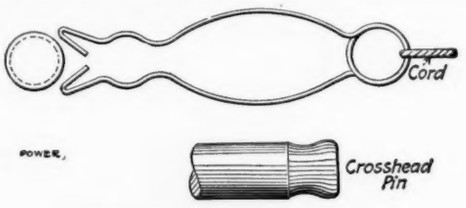
This, however, did not explain why the fuses blew when the switch was opened; obviously it should be just the reverse. A second examination proved this to be true and that what my friend had assumed to be the open position of the switch was really the closed position and when he closed the switch he had a dead short-circuit across the line and naturally the fuses blew. The mistake was rectified by cutting out the section *AB*, disconnecting the section *CD* at *D* and reconnecting it at *E;* also connecting the switch properly.

Chicago, Ill. Thomas G. Thurston.

Handy Hook for Indicator Cord

In the Nov. 4 issue, page 637, Mr. Baumeister describes an indicator cord hook for use with high-speed engines. If used on an inclosed type of engine, running between 275 and 300 r.p.m., I think the hook would give trouble in staying on the pin.

At one time I was going to indicate a 12x14-in. inclosed engine, running at 276 r.p.m., and encountered



INDICATOR CORD HOOK

difficulties in getting the hook to stay on the pin. To overcome this trouble I made a hook, as shown by the accompanying sketch.

It is used as follows: Hold the hook so that when the crosshead travels on its return stroke the pin will strike the points of the hook, opening them up, but as they close before the crosshead begins its opposite stroke, the hook and cord are carried with it. To unhook, run the hand down on the cord until it strikes the hook. The crosshead will then travel in the return direction until the pin comes to the enlarged part at the hook when, with a little sidewise pull, the hook is easily disengaged from the crosshead pin.

FRED W. SCHNEIDER.

Clay Center, Ohio.

Exhaust Muffler vs. Back Pressure

The sketch, Fig. 1, shows how the exhaust muffler was arranged on an oil engine and the manner in which changes were made in order to have the engine produce

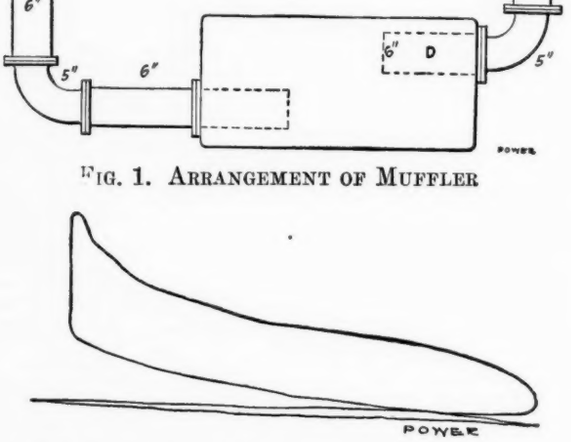


FIG. 1. ARRANGEMENT OF MUFFLER

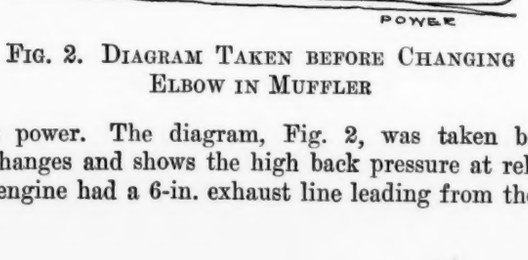


FIG. 2. DIAGRAM TAKEN BEFORE CHANGING ELBOW IN MUFFLER

more power. The diagram, Fig. 2, was taken before the changes and shows the high back pressure at release. The engine had a 6-in. exhaust line leading from the engine to the flanged elbow, which had a 5-in. opening; the extension inside the muffler was 6 in. At the opposite end the muffler had a short section of 6-in. pipe and another 5-in. elbow with an upward extending exhaust pipe 6 in. in diameter.

The 6-in. line and fittings had a cross-sectional area of 28.27 sq.in. and the 5-in. elbows an area of only 19.63, a difference of 8.64 in., the equivalent of a $3\frac{5}{16}$-in. circle. It is evident what a great difference this would have upon the working of the engine by causing excessive back pressure. The diagram, Fig. 3, was taken after two new 6-in. elbows had been substituted for the 5-in. elbows, and shows substantional reduction in back pressure. The diagrams were taken with a 100-lb. spring while the engine was running at 220 r.p.m.

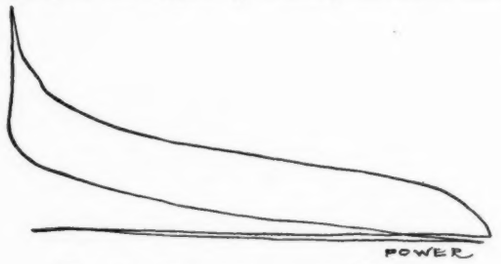


FIG. 3. DIAGRAM AFTER MAKING CHANGE IN MUFFLER

R. C. HAY.

Covington, Va.

Use of Tables

Engineers often fail to obtain benefit from valuable data because of the inconvenience of the arithmetical processes required for converting quantities into suitable units. For instance, water-meter readings are in cubic feet or gallons which have to be converted into pounds to determine the pounds of water evaporated per pound of coal, or gallons or cubic feet have to be converted into cubic inches as in determination of pump capacities.

When computations require the use of a constant multiplier, I have found this commonly used method convenient. Set out in tabular form for ready reference the products of the coefficient multiplied by the units from 1 to 10 and thus save intricate multiplications by dividing a multiplicand into tenths, hundredths, etc., and then take the sum of the products thus obtained with the proper number of zeros affixed to each term of the multiplicand. A simple example will suffice to show how meter readings in cubic feet may be converted into pounds of water at any average temperature, as 50 deg. F.

For this purpose set out a table for reference as follows:

1 cu.ft. of water weighs	62.41 lb.
2 cu.ft. of water weigh	124.82 lb.
3 cu.ft. of water weigh	187.23 lb.
4 cu.ft. of water weigh	249.64 lb.
5 cu.ft. of water weigh	312.05 lb.
6 cu.ft. of water weigh	374.46 lb.
7 cu.ft. of water weigh	436.87 lb.
8 cu.ft. of water weigh	499.28 lb.
9 cu.ft. of water weigh	561.69 lb.
10 cu.ft. of water weigh	624.10 lb.

A meter reading, such as 13,720 cu.ft., is then readily converted in pounds by affixing the appropriate number of zeros to the tabulated product for each figure and taking the sum as follows:

10,000 cu.ft.	= 624,100 lb.
3,000 cu.ft.	= 187,230 lb.
700 cu.ft.	= 43,687 lb.
20 cu.ft.	= 1,248.2 lb.
13,720 cu.ft.	= 856,265.2 lb.

In the same manner, tables of the products 1 to 10 can be constructed with little trouble for ready reference for converting cubic feet to gallons, gallons to pounds, gallons to cubic inches, or for greater convenience in computing horsepower for different mean effective pressures using a given horsepower constant. With a few such tables adapted to his individual requirements, an engineer will find the task of making power-plant computations much less tax on his time and patience.

Medford, Mass. L. E. THOMPSON.

Running Cross-Compound Engine on Light Load

H. Rollins asks for discussion on this subject.

My method is to evenly distribute the load on the cylinders unless it is extremely light. On starting up, the best practice is to completely drain the main steam line, the cylinders and the receiver during the warming-up process. There is no occasion for apprehension on account of the high-pressure cylinder pulling water from the receiver as the pressure in the cylinder prevents the condensate from backing up.

A more imminent danger lies in the low-pressure cylinder expanding the steam to a lower vacuum than that maintained in the condenser. Such an occurrence might cause enough water to be drawn into the cylinder to wreck it. Therefore, I think it advisable to put most of the work on the low-pressure cylinder under extremely light load conditions to prevent the expansion of steam from lowering the pressure below that in the condenser.

Of course, similar conditions may arise in the receiver, due to the sudden diminishing of the load, when the receiver pressure may momentarily exceed the terminal pressure in the high-pressure cylinder. The remedy for this is a dependable steam trap.

It is impossible to lay down a rule for draining applicable to all engines or to estimate the possible results from water in the cylinder. I have seen an engine with the exhaust pipe rising above a 10-story building take over water and discharge it from the top of the pipe like a waterspout (for from 30 to 60 sec. at a time, notwithstanding the separator in the steam line), without the engine being damaged. On the other hand, engines have been wrecked by a single slug of water. There is little danger so long as the water does not exceed the capacity of the clearance space; in practice, however, much depends on the make of the engine, the lost motion in the journals, etc.

Mr. Rollins states: "I heartily agree that it (the receiver) should be well drained, but cannot see how an ordinary trap can drain a receiver when it has no pressure to make it work, or when the cutoff is so short that there is a vacuum in the receiver as the result."

I cannot conceive how such conditions are possible. Were the drain piped to the atmosphere, as Mr. Rollins assumes, the atmospheric pressure would not prevent the condensate from escaping, as it would enter the receiver, destroy the vacuum, and enable the trap to work by gravity. On the other hand, it would also raise the receiver pressure above the terminal pressure in the high-pressure cylinder, causing water to be drawn into it, possibly with disastrous results.

The best way of avoiding trouble from water is to connect the trap into the condenser. This would effect better operating conditions for the trap, and prevent the atmosphere from destroying the receiver vacuum.

As regards the reheating coil in the receiver, it is constructed for the purpose of circulating live steam at full boiler pressure, and I do not think that there is more danger to be expected from that source than from the bursting of the main steam or any other pipe carrying high-pressure steam.

Washington, D. C. VICTOR BONN.

Pump with Cracked Spider

One morning while looking over the pumps in an ice plant I noticed that one of the duplex pumps was running in a most unusual way. It made three strokes all right, but the next one was slow and laboring. Steam could be heard going through the exhaust line just as if the steam and exhaust ports opened into each other. An examination showed the valve-gear to be in working order; the valves were properly set and no pieces had been broken from the valve or ribs; the piston rings were not loose enough to require a new set.

Finally the pump was taken apart and it was discovered that a steam-piston spider had close to the rod a small crack that ran into a sand hole, so that steam found its way through. When steam was admitted to the head end of the cylinder the rings held tight, but at the other end the steam went through the crack and sand hole, passing the follower plate and blowing directly into the exhaust. An ⅛-in. boiler-plate patch stopped the trouble.

Chicago, Ill. A. G. SOLOMON.

The Slow-Speed Magneto

The desire for simplicity and reliability in gas-engine details has led to the adoption by many manufacturers of the slow-speed positive-driven magneto as the source of ignition current.

The one here described has been in use for three years at Oklahoma University and has proved eminently effective for make-and-break ignition. The magneto is a single-phase alternator, of the bobbin-wound type, as shown in Fig. 1. One end of the winding is grounded to the frame of the machine, and the other end is connected to the insulated end of the shaft against the center of which is the collector brush. One wire answers from the brush to the insulated igniter terminal.

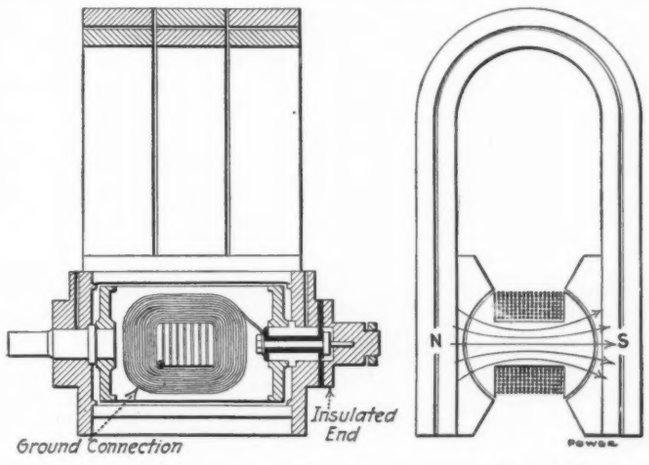


FIG. 1. SECTIONAL ELEVATIONS OF MAGNETO

Fig. 2 is from a photograph taken by the oscillograph in the electrical laboratory of the university, and shows

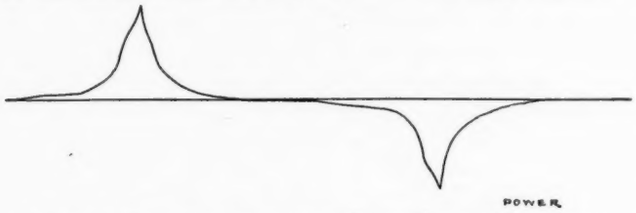


FIG. 2. OSCILLOGRAPH FOR SLOW-SPEED MAGNETO

the current distribution for one revolution. The magneto is so timed that the igniter snaps at the peak of maximum current, and this is strong enough to start an engine at the ordinary hand-turning speed of about 50 r.p.m. The marks on the shaft collar and the frame of the machine indicate this maximum point.

Norman, Okla. WILLIAM AITKENHEAD.

Running Fans in Parallel

This is a usual occurrence in today's applications but the case L. B. Lent described in the Dec. 16 issue of POWER is special. The most common arrangement of parallel application is with two separate fans on one shaft driven by a single motor. Such units as the turbine forced-draft sets installed in recent years by the New York Edison Co. are typical of this simple arrangement, and those installed on our modern torpedo-boat destroyers operate with two separate turbine-driven forced-draft fan units discharging into a closed fire room.

Both of these methods have proved successful. Experience teaches, however, that to prevent one fan from taking the load from the other, the two fans, not driven by one contiguous shaft, should have their speeds controlled by one regulating valve or throttle control. This control was symmetrically located with reference to the fan units and thus each of the turbines had steam delivered to their cases under identically the same conditions. The fan units were made from the same templates and dies so that they each carried an equal part of the load, due to their like characteristics. With electrically driven fan units in parallel the same care in selecting a single control for the motor units makes the problem simple and one need not feel the necessity of pitot-tube readings.

Personal experience on a recent test has shown that Mr. Lent's article should receive careful thought by those running more than one fan with common intake or discharge system. The owner was operating one fan at 315 r.p.m. by one throttle and the other at 356 r.p.m. by another throttle valve. The consequence was, that whereas either fan could have delivered 32,000 cu.ft. per min. against 2½ in. resistance at 356 r.p.m., air at 65 deg. F., both fans together gave but 41,000 cu.ft. per min. against 2½ in. One fan was stealing practically all the load from the other and the idle one consumed 10.5 b.hp. without doing much useful work.

I wish to supplement Mr. Lent's statement as to the pressure of a fan running blocked tight, the discharge pipe entirely closed, as being equal to that due to the lineal speed of the blades. This pressure is usually greater than that due to the lineal speed of the tip of the blades. I know of multivane fans that put up 2.6 times the pressure due to tip speed. This is true regardless of the double- or single-inlet, double- or single-width features in fans with one or more outlets. Even on fans with convex forward rotation of blades I have made tests where they would deliver their rated capacities against 53 per cent. greater pressure than tip-speed pressure and deliver the air at maximum efficiencies.

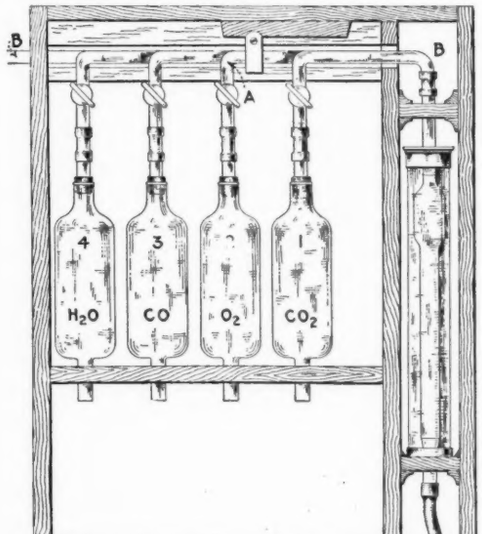
It would seem in Mr. Lent's case that instead of having to boost the speed of the fan running light above the speed (r.p.m.) of the fan running at higher speed in order to start a flow, the air flow should have started from the idle fan as soon as its tip-speed pressure equaled the static resistance maintained by the original fan.

However, with a system already installed, it is readily seen that by throwing in the second fan one cannot expect to double the present delivery through the system except by increasing the r.p.m. of both fans. This produces the extra pressure necessary to overcome the added resistance caused by twice the volume flowing through the system. This pressure resistance would be four times the original static pressure resistance maintained at the entrance to the old system.

Boston, Mass. H. H. VALIQUET.

Improvement for Orsat

I have made an improvement on the Orsat apparatus which does away with the gas bags attached to the absorption pipettes. This can be done by fitting a fourth pipette in the case. Practically all Orsat apparatus are built with sufficient room for this extra pipette. The rear legs of all four pipettes are then connected to a glass connecting tube or header *A*, as in the sketch, mounted in back of the main connecting tube *B*. The extra pipette



VIEW OF ORSAT FROM REAR, SHOWING ADDITIONAL PIPETTE AND CONNECTIONS

is filled with water to the same level as the three containing the reagents and its front leg is left open to the atmosphere. Thus, a water seal is provided and the air in the back leg of any of the working pipettes is stored in the back leg of this end pipette when displaced by the manipulation of a gas sample.

The advantages of this arrangement are a neater looking equipment and the elimination of trouble due to the rubber gas bags developing leaks or becoming disconnected through any cause.

Bloomfield, N. J. G. A. DEGRAAF.

Engineers' Study Course

Trigonometry--XI

Last Lesson's Answers

46. Given $a = 9$, $b = 12$ and $c = 15$.

This is a Case IV problem and the three angles are found by the three forms of equation 31 (last lesson).

$$cos\ A = \frac{12^2 + 15^2 - 9^2}{2 \times 12 \times 15} = \frac{288}{360} = 0.8$$

Therefore, angle $A = 37$ deg., closely.

$$cos\ B = \frac{9^2 + 15^2 - 12^2}{2 \times 9 \times 15} = \frac{162}{270} = 0.6$$

Therefore, angle $B = 53$ deg., closely.

$$cos\ C = \frac{9^2 + 12^2 - 15^2}{2 \times 9 \times 12} = \frac{0}{216} = 0$$

Therefore, angle $C = 90$ deg.

Check:

$$37 + 53 + 90 = 180$$

This proved to be a right triangle and it could have been predicted at the outset, as the sides are respectively proportional to 3, 4 and 5.

47. Given $a = 94.596$, $b = 104.653$ and $c = 100$.

This also is a Case IV problem and is solved in the same way as the last.

$$cos\ A = \frac{104.653^2 + 100^2 - 94.596^2}{2 \times 104.653 \times 100} = 0.5736$$

Therefore, angle $A = 55$ deg.

$$cos\ B = \frac{94.596^2 + 100^2 - 104.653^2}{2 \times 94.596 \times 100} = 0.4226$$

Therefore, angle $B = 65$ deg.

$$cos\ C = \frac{94.596^2 + 104.653^2 - 100^2}{2 \times 94.596 \times 104.653} = 0.5$$

Therefore, angle $C = 60$ deg.

48. Calling the three sides of the pond a (100 ft.), b (150 ft.) and c (75 ft.), the solution will be as in the two previous problems

$$cos\ A = \frac{150^2 + 75^2 - 100^2}{2 \times 150 \times 75} = \frac{18{,}125}{22{,}500} = 0.8055$$

Therefore, the angle $A = 36\frac{1}{3}$ deg., about.

$$cos\ B = \frac{100^2 + 75^2 - 150^2}{2 \times 100 \times 75} = \frac{-6875}{15{,}000} = -0.4583$$

The sign being negative, the angle B is of the second quadrant or greater than 90 deg.; therefore it will be the supplement of the angle found from the table, or

$$180 - 62.7 = 117.3 \text{ or about } 117\tfrac{1}{3} \text{ deg.}$$

$$cos\ C = \frac{100^2 + 150^2 - 75^2}{2 \times 100 \times 150} = \frac{26{,}875}{30{,}000} = 0.8958$$

Therefore, the angle $C = 26\frac{1}{3}$ deg., about.

Check:

$$36\tfrac{1}{3} + 117\tfrac{1}{3} + 26\tfrac{1}{3} = 180 \text{ deg.}$$

49. First find the area of the surface of the pond by equation 32 (last lesson).

$$area = \tfrac{1}{2} \times 100 \times 75 \times 0.8886 = 3332.25 \text{ sq.ft.}$$

The depth being 5 ft., the volume will be

$$3332.25 \times 5 = 16{,}661.25 \text{ cu.ft.}$$

or, there being 7.48 gal. to 1 cu.ft.,

$$16{,}661.25 \times 7.48 = 124{,}626.15 \text{ gal.}$$

50. The base of the triangular guard being 6 ft. and its altitude 8 ft., its area is

$$area = \tfrac{1}{2} \times 6 \times 8 = 24 \text{ ft.}$$

Then from equation 32 the sine of the angle between the two known sides may be found

$$24 = \tfrac{1}{2} \times 8\tfrac{1}{2} \times 6 \times sin\ B$$

$$sin\ B = \frac{24}{\frac{1}{2} \times 8\frac{1}{2} \times 6} = \frac{24}{25.5} = 0.9412$$

Therefore, angle $B = 70\frac{1}{4}$ deg., closely.

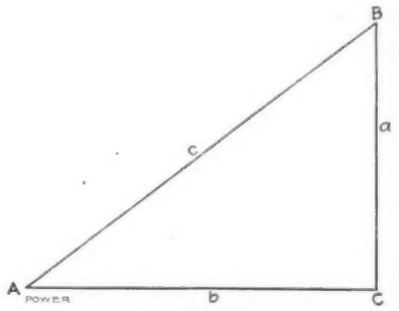


Fig. 13

The angle required, however, is the one opposite the base, or C, making this part a Case III problem. Using the first method for that case:

$$tan\ \tfrac{1}{2}(A - C) = \frac{8\frac{1}{2} - 6}{8\frac{1}{2} + 6} \times tan\ \tfrac{1}{2}(180 - 70\tfrac{1}{4})$$

$$= \frac{2.5}{14.5} \times 1.4216 = 0.2451$$

Therefore $\tfrac{1}{2}(A - C) = 13.77$ deg., about, and

$$C = \tfrac{1}{2}(A + C) - \tfrac{1}{2}(A - C) = 54.88 - 13.77 = 41.11$$

or practically 41 deg.

Review

Trigonometry is a branch of mathematics mainly concerned with the solution of triangles and involving certain ratios of angles and sides, known as functions of angles.

Given a side and any other two of the six parts of a triangle—the three sides and the three angles—and the unknown parts may be determined.

The ratios known as trigonometrical functions of an angle are

$$sine = \frac{opposite\ side}{hypotenuse} \qquad sin\ A = \frac{a}{c} \text{ (Fig. 13)}$$

$$cosine = \frac{adjacent\ side}{hypotenuse} \qquad cos\ A = \frac{b}{c}$$

$$tangent = \frac{opposite\ side}{adjacent\ side} \qquad \tan A = \frac{a}{b}$$

$$cotangent = \frac{adjacent\ side}{opposite\ side} \qquad \cot A = \frac{b}{a}$$

$$secant = \frac{hypotenuse}{adjacent\ side} \qquad \sec A = \frac{c}{b}$$

$$cosecant = \frac{hypotenuse}{opposite\ side} \qquad \csc A = \frac{c}{a}$$

$$versed\ sine = 1 - cosine \qquad vers\ A = \frac{c - b}{c}$$

$$versed\ cosine = 1 - sine \qquad covers\ A = \frac{c - a}{c}$$

The complement of an angle is the difference between 90 deg. and the angle. Any function is equal to the co-named function of the complementary angle.

The supplement of an angle is the difference between 180 deg. and the angle.

The sum of the three angles of a triangle is 180 deg. Therefore, any one of the angles is the supplement of the sum of the other two, and in a right triangle the acute angles are complements of one another

Angles from 0 to 90 deg. are of the first quadrant, 90 to 180 deg. of the second, 180 to 270 deg. of the third and 270 to 360 deg. of the fourth quadrant.

For angles of the various quadrants the signs of the functions are

	sin	cos	tan	cot	sec	csc
1st quadrant	+	+	+	+	+	+
2nd quadrant	+	−	−	+	−	+
3rd quadrant	−	−	+	+	−	−
4th quadrant	−	+	−	−	+	−

Following is a short table of the values of the functions for the more common angles:

Angle	sin	cos	tan	cot	sec	csc
0°	0	1	0	∞	1	∞
30°	$\frac{1}{2}$	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{3}}$	$\sqrt{3}$	$\frac{2}{\sqrt{3}}$	2
45°	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	1	1	$\sqrt{2}$	$\sqrt{2}$
60°	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$	$\sqrt{3}$	$\frac{1}{\sqrt{3}}$	2	$\frac{2}{\sqrt{3}}$
90°	1	0	∞	0	∞	1
120°	$\frac{\sqrt{3}}{2}$	$-\frac{1}{2}$	$-\sqrt{3}$	$-\frac{1}{\sqrt{3}}$	−2	$\frac{2}{\sqrt{3}}$
135°	$\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$	−1	−1	$-\sqrt{2}$	$\sqrt{2}$
150°	$\frac{1}{2}$	$-\frac{\sqrt{3}}{2}$	$-\frac{1}{\sqrt{3}}$	$-\sqrt{3}$	$-\frac{2}{\sqrt{3}}$	2
180°	0	−1	0	∞	−1	∞
270°	−1	0	∞	0	∞	−1
360°	0	1	0	∞	1	∞

(∞ is the sign for infinity and means the increasing of a number beyond all limits. As applied to a line representing a function it is an imaginary one continuing throughout space without an end.)

The ten fundamental relations which the trigonometrical functions of any angle bear to one another are:

$$\sin^2 A + \cos^2 A = 1$$

$$\tan A = \frac{\sin A}{\cos A}$$

$$\cot A = \frac{\cos A}{\sin A}$$

$$\cot A = \frac{1}{\tan A}$$

$$\sec A = \frac{1}{\cos A}$$

$$\csc A = \frac{1}{\sin A}$$

$$\sec^2 A = 1 + \tan^2 A$$

$$\csc^2 A = 1 + \cot^2 A$$

$$vers\ A = 1 - \cos A$$

$$covers\ A = 1 - \sin A$$

For the functions of the sum and difference of two angles there are eight principal formulas, as follows:

$$\sin (A + B) = \sin A \cos B + \cos A \sin B$$

$$\sin (A - B) = \sin A \cos B - \cos A \sin B$$

$$\cos (A + B) = \cos A \cos B - \sin A \sin B$$

$$\cos (A - B) = \cos A \cos B + \sin A \sin B$$

$$\tan (A + B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$$

$$\tan (A - B) = \frac{\tan A - \tan B}{1 + \tan A \tan B}$$

$$\cot (A + B) = \frac{\cot A \cot B - 1}{\cot B + \cot A}$$

$$\cot (A - B) = \frac{\cot A \cot B + 1}{\cot B - \cot A}$$

For the functions of twice an angle there are four principal formulas, which are

$$\sin 2A = 2 \sin A \cos A$$

$$\cos 2A = \cos^2 A - \sin^2 A$$

$$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$$

$$\cot 2A = \frac{\cot^2 A - 1}{2 \cot A}$$

For the functions of half an angle, also, there are four principal formulas:

$$\sin \tfrac{1}{2} A = \pm \sqrt{\tfrac{1}{2}(1 - \cos A)}$$

$$\cos \tfrac{1}{2} A = \pm \sqrt{\tfrac{1}{2}(1 + \cos A)}$$

$$\tan \tfrac{1}{2} A = \pm \sqrt{\frac{1 - \cos A}{1 + \cos A}}$$

$$\cot \tfrac{1}{2} A = \pm \sqrt{\frac{1 + \cos A}{1 - \cos A}}$$

Any right triangle can be solved if one side and an acute angle or two sides are given. When two sides are known the third can be found by the relation that the square of the hypotenuse is equal to the sum of the squares of the other two sides. The angles are found by applying the formulas for the functional relations given above, as

$$sine = \frac{opposite\ side}{hypotenuse},\ etc.$$

All oblique triangle problems come under four cases:

Case 1. Given one side and two angles. The third angle is found by subtracting the sum of the two known angles from 180 deg. and the sides by the application of the Law of Sines: The sides of a triangle are proportional to the sines of the opposite angles; or, expressed,

$$\frac{a}{b} = \frac{\sin A}{\sin B},\ \text{(Figs. 14 or 15)}$$

Case II. Given two sides and an angle opposite one of them. By the Law of Sines first the angle opposite the other known side, then the third angle and finally the third side are found.

Case III. Given two sides and the included angle.

First Method. The sum of the other two angles will equal 180 deg. minus the given angle and the difference between the other two angles may be found by the Law of Tangents: The sum of the two sides of a triangle is to their difference as the tangent of half the sum of the opposite angles is to the tangent of half their difference; expressed

$$\frac{a+b}{a-b} = \frac{tan\ \frac{1}{2}\ (A+B)}{tan\ \frac{1}{2}\ (A-B)}$$

or

$$tan\ \tfrac{1}{2}\ (A-B) = \frac{a-b}{a+b} \times tan\ \tfrac{1}{2}\ (A+B)$$

Then each of the two unknown angles can be found, for

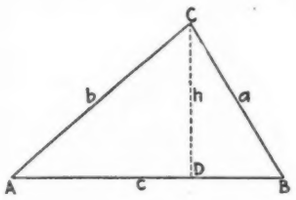


FIG. 14

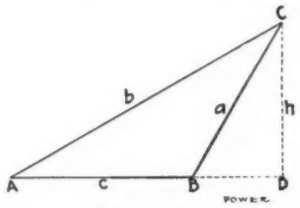


FIG. 15

the larger will be equal to half their sum plus half their difference; expressed

$$A = \tfrac{1}{2}\ (A+B) + \tfrac{1}{2}\ (A-B)$$

and the smaller will be equal to half their sum minus half their difference; expressed

$$B = \tfrac{1}{2}\ (A+B) - \tfrac{1}{2}\ (A-B)$$

The third side can then be found by the Law of Sines.

Second Method. The third side may be found directly by the Law of Cosines: The square of any side of a triangle is equal to the sum of the squares of the other two sides, less twice the product of the sides and the cosine of the included angle; expressed

$$a^2 = b^2 + c^2 - 2\ bc\ cos\ A$$

and the two unknown angles found by the Law of Sines.

Case IV. Given the three sides. The angles may be found directly by the Law of Cosines.

The area of any triangle is equal to one-half the product of its base by its altitude; expressed

$$area = \tfrac{1}{2}\ ch \quad \text{(Figs. 14 or 15)}$$

or, one-half the product of two sides and the sine of the included angle; expressed

$$area = \tfrac{1}{2}\ ac\ sin\ B$$

Resistance of Tungsten at High Temperatures—Accurate measurements on the electric resistance of tungsten at high temperatures have been made by Pirali. He uses a strip of this material 2.4 in. long, 0.05 in. wide, and 0.002 in. thick, mounted in an exhausted bulb. The strip is soldered to a pair of very fine wires as a support, so as to have the heat radiation uniform; which is not the case where the filament is attached to the support of an ordinary lamp, for the support carries away the heat from the ends of the filament and makes these cooler than the remainder. He takes the temperature of the tungsten strip by using a Holborn pyrometer, and finds that the ratio of the resistance at high heats to the resistance in the cold at 20 deg. C. (taken as unity) is 7 for 1200 deg. C., 10 for 1600, and 12 for 1900 C.

OVER THE SPILLWAY

JUST JESTS, JABS, JOSHES AND JUMBLES

"Would you live in a vacuum?" asks George Fitch in "Collier's." Not on our suburban home we wouldn't. There's nothing in it!

The hydro-electric plant is much more than a generator of juice, if we accept this piece of pretty sentiment from "Compressed Air":

"Our desert spots are made to blossom like the rose, transfigured from barren arid wastes into gardens of flowers and fields of grain, by the use of hydro-electric power."

If you wish to live to good old age, take a spoonful of lubricating oil every day, says Doctor Lane, a famous English surgeon. That's all right for the Eskimos, but who wants to be an Eskimo?

Up to May 30, 1913, the Panama Canal cost $295,587,148.41, and to keep the Canal Zone healthy over $16,000,000 was expended. These total to a comfortable little bunch of money, but if it all had to be done over again, 'twould be worth it.

Vice-President Marshall has said that "500,000 young people annually come from our schools to achieve success in life, and 400,000 are failures." This is hard to believe. While we cannot all hope to be Vice-Presidents, most of us are earning a decent living, educating our children and putting by a dollar against the rainy day. Aren't we a success in a small way, and hasn't Success left her mark among the humble as well as the great? Sometimes T. Riley Marshall's utterances evince a need for pepsin right after his meals.

Happen to know Billy Dugan, over to Butler, N. J.? Well, anyhow, Billy thinks we fell over the spillway on Jan. 1, for his Jan. 6 "Power" had several blank pages. Once in a short lifetime a sheet will creep into the paper printed on one side only. Our mechanical department is only human—and so is Billy, for he forgives us.

"It would be obvious to any mechanic that a right-handed drill would be used to extract a left-handed screw, and a left-handed drill to extract a right-handed screw," says a patent examiner. The "Valve World" remarks that "C. L. Redfield, M. E., a Chicago patent solicitor, evidently with a memory of his own apprentice days, observes that now, in addition to hunting for a left-hand monkey wrench or a half-round square, the poor apprentice will be required to drill left-handed holes."

When Doctor Humphreys urged the choosing of engineers for public-service commissioners, did he have in mind the Massachusetts Board's ready consent for the New Haven's latest scheme to exploit its property for the bankers' benefit? Bleeding stockholders of $68,000,000 is scattering the gore rather too promiscus. Don't believe this proceeding would have been permitted if this board had been composed of engineers who have ethics on tap.

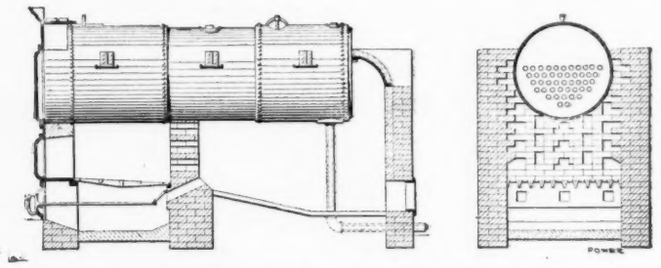
"One day on approaching our factory," writes an American engineer in Cuba, "I noticed a great cloud of smoke, oily and black, rolling out of the chimneys and blotting out the surrounding landscape. I went to the boiler room and gave the firemen a good dressing-down for allowing so much smoke to escape, telling them that it was throwing money away, and that if they could not fire better I would have to discharge them. I thought no more of it till the next morning when on entering the engine room I found the chief mechanic jubilant over some joke. He told me that the chief fireman, a negro, had come to him with tears in his eyes and had said: 'Mr. U says that we must not let the smoke go out of the chimney; if we do he will discharge us. Now, if the smoke cannot go out of the chimney, where can we put it?'"

Building a Smokeless Furnace

By E. E. Clock

All smoky furnaces need an increased bulk of firebrick to absorb heat at the time of greatest production in order to give it off at times of least heat production. A furnace must be reverberating to successfully prevent smoke, and with a properly designed furnace of heavy arches and reverberatory weight of firebrick there is no need of smoke. Smoke from such a furnace is the result of carelessness.

It is with the common type of furnace usually associated with a horizontal, return-tubular boiler that I wish to deal. Such a furnace can be constructed with



Design for a Smokeless Boiler Furnace

sufficient reverberatory weight and surface of firebrick to successfully burn any grade of hard or soft coal without smoke, providing one boiler is not compelled to do the work of two.

The standard plans for setting return-tubular boilers, it is said, originated in Pittsburgh. These plans have been handed along until it is time the authorities took cognizance and provided a fine and imprisonment for anyone found guilty of constructing such a boiler furnace within the city limits.

Municipal control of the construction of all coal-burning furnaces should be had and free plans furnished by the municipality; if smoke-making boiler plants were prohibited atmospheric purity would be greatly improved.

The side walls of a reverberatory furnace should be ribbed or corrugated. Set one row of bricks end to end, with the side exposed in the usual way; set the next row side by side, the end of each brick protruding half its length, alternating the courses so that one course is in half a brick, the next one out half a brick to the top of the setting, as shown in the illustration. This setting should not begin until above the fire line at the grates, and above the ash line at the combustion chamber. The bridgewall should be built 18 in. thick and right up to the boiler, making a complete cross wall from side to side. This wall above the fire line is to be perforated with holes or slots of sufficient area to equal the area of the air space of the grate.

In laying the foundation for such a bridgewall, four hollow wooden forms, about 3x4 in., should be placed so that one end will protrude through the front, below the grate, and the other end through the back of the wall just below the lowest line of holes or slots, arranging stoppers on long rods to come through the front of the furnace below the grates for controlling the draft through these flues.

The grates will then send to the combustion chamber gases that are properly heated and mixed. Thus by regulating the admission of air through the ducts below the grates, according to the weight and imperviousness of the contents of the grates, one will be able to control the action of the furnace to the desired combustion of all combustible; the most important action will be in firing only one side at a time. Such a furnace should be provided with peep-holes to the combustion chamber. This furnace will burn soft coal with no signs of smoke at the chimney.

It should be remembered that the boiler itself is a condenser or arrester of combustion, therefore the products of combustion should be kept away from the cool surfaces of the boiler as far as possible until they are thoroughly mixed with air and heated. Fire one side of the furnace at a time, and when the furnace door is open the damper in the uptake of that boiler should be closed, automatically if possible.

It is not absolutely necessary that the perforated wall be built on top of the bridgewall; it can go back a foot or so. Many furnaces can be helped by placing a perforated mass of firebrick in the combustion chamber and introducing proper firing methods.

Graphical Determination of Trigonometric Functions

The Trigograph, a small reproduction of which is shown in Fig. 1, is a chart with which it is possible to obtain the natural functions of angles graphically to slide-rule accuracy.

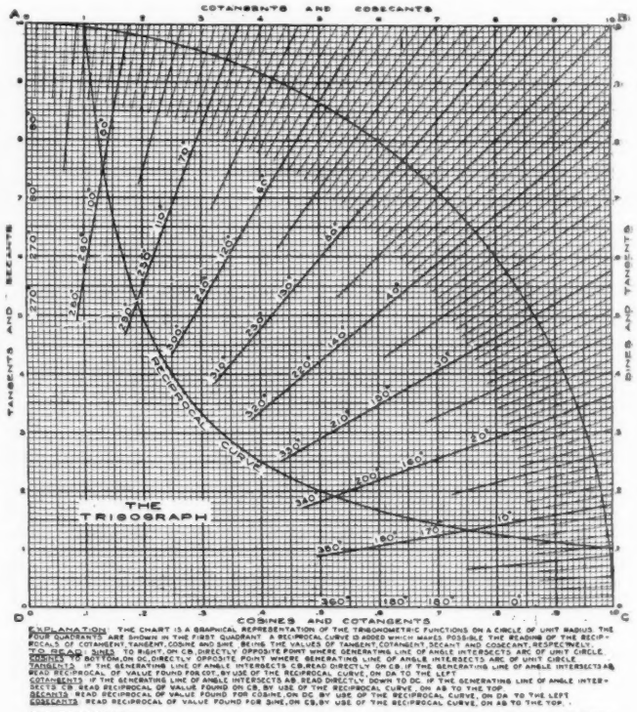

COTANGENTS AND COSECANTS
TANGENTS AND SECANTS
SINES AND COSINES
RECIPROCAL SCALE
THE TRIOGRAPH
COSINES AND COTANGENTS
EXPLANATION: THE CHART IS A GRAPHICAL REPRESENTATION OF THE TRIGONOMETRIC FUNCTIONS ON A CIRCLE OF UNIT RADIUS. THE FOUR QUADRANTS ARE SHOWN IN THE FIRST QUADRANT. A RECIPROCAL CURVE IS ADDED WHICH MAKES POSSIBLE THE READING OF THE RECIPROCALS OF COTANGENT, TANGENT, COSINE AND SINE, BEING THE VALUES OF TANGENT, COTANGENT, SECANT AND COSECANT, RESPECTIVELY.
TO READ SINES: TO RIGHT, ON CB, DIRECTLY OPPOSITE POINT WHERE GENERATING LINE OF ANGLE INTERSECTS ARC OF UNIT CIRCLE.
COSINES: TO BOTTOM, ON DC, DIRECTLY OPPOSITE POINT WHERE GENERATING LINE OF ANGLE INTERSECTS ARC OF UNIT CIRCLE.
TANGENTS: IF THE GENERATING LINE OF ANGLE INTERSECTS CB, READ DIRECTLY ON CB; IF THE GENERATING LINE OF ANGLE INTERSECTS AB, READ RECIPROCAL OF VALUE FOUND FOR COT. BY USE OF THE RECIPROCAL CURVE, ON DA TO THE LEFT.
COTANGENTS: IF THE GENERATING LINE OF ANGLE INTERSECTS AB, READ DIRECTLY DOWN TO DC. IF THE GENERATING LINE OF ANGLE INTERSECTS CB READ RECIPROCAL OF VALUE FOUND ON CB, BY USE OF THE RECIPROCAL CURVE, ON AB TO THE TOP.
SECANTS: READ RECIPROCAL OF VALUE FOUND FOR COSINE, ON DC BY USE OF THE RECIPROCAL CURVE, ON DA TO THE LEFT.
COSECANTS: READ RECIPROCAL OF VALUE FOUND FOR SINE, ON CB, BY USE OF THE RECIPROCAL CURVE, ON AB TO THE TOP.
THE TRIOGRAPH
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Fig. 1. The Triograph. Reproduction about Half Size

The quadrant shown is one of unit radius and is divided into 90 deg. Angles having the same numerical values (but not necessarily of the same sign) are marked in their corresponding positions. This enables one to read the natural functions for any angle from 0 to 360 deg.

The method of reading will be understood by referring to Fig. 2. The square *ABCD* is divided into equal spaces.

The divisions on *AB* represent numbers from 0 to 10, on *CB* from 0 to 1, on *DC* from 0 to 1 and on *DA* from 0 to 10. *AKC* is a circle described about *D* as a center and has a radius equal to unity. *LMN* is a hyperbolic curve and has for its equation $Y = 1/X$. It is plotted using values on *DC* as abscissas and values on *DA* as ordinates. Thus, 0.2 on *DC* corresponds to 5, or the reciprocal of 0.2,

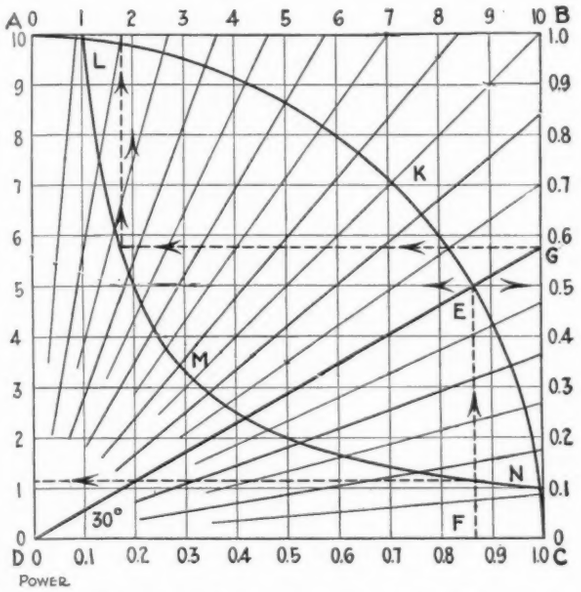

FIG. 2. DIAGRAM ILLUSTRATING THE USE OF THE TRIGOGRAPH

on *DA*. It will be noticed that if this same curve be plotted, using the values on *CB* as abscissas and the values on *AB* as ordinates the curve will fall along the same points. Therefore, with this curve one may find the reciprocal of any value on *DC*, or the reciprocal of any value on *CB*, by locating the corresponding values on *DA* or on *AB*.

The functions of any angle, for example, 30 deg., which on the diagram is the angle *GDC*, are found as follows:

Sine—Drop a line as *EF* from the point where *DG* intersects the circumference of the unit circle. Here is a right triangle, *DFED*, the angle at the vertex *D* being 30 deg. Then *FE/DE* equals *sin* 30°. *DE* equals 1, being equal to the unit radius. Therefore, *FE* equals *sin* 30°, and its value is 0.5, as indicated by arrows on *CB* to the right.

Cosine—Considering the same triangle, *DF /DE* equals *cos* 30°. Therefore, *DF* equals *cos* 30° and its value is 0.866 as read directly on *DC*.

Tangent—Now, refer to the triangle *DCGD*, which is similar to the triangle *DFED*, the angle at the vertex *F* being 30 deg. Then, *CG/DC* equals *tan* 30°. *DC* equals 1 (by construction). Therefore, *CG* equals *tan* 30° and its value is 0.577 as read directly on *CB*.

Cotangent—Since *cot* 30° equals 1/ *tan* 30°, read the reciprocal of 0.577, which is found on *CB*, using the curve *LMN*, on *AB* at the top. This is indicated by arrows and the value found is 1.73.

Secant—Since *sec* 30° equals 1/ *cos* 30°, read the reciprocal of 0.866 as found for *cos* 30 deg. on *CD*, using the reciprocal curve on *DA* to the left. This is indicated by arrows and the value thus found is 1.15, which is the natural secant of 30 deg.

Cosecant—Since *csc* 30° equals 1/ *sin* 30°, read the reciprocal of 0.5 as found for *sin* 30° on *CB*, using the reciprocal curve on *AB* to the top. This is indicated by arrows and the value thus found is 2, which is the cosecant of 30 deg.

For angles over 45 deg. the functions are found as follows: Read the cotangents directly down to *CD* and the tangents, using the curve *LMN* on *DA* to the left; the other functions are found in the same manner as those of angles under 45 deg.

The Trigograph has been copyrighted by A. D. Burton, 214 North Mayfield Ave., Chicago, Ill., and is furnished in 9x12-in. and 22x24-in. sizes.

Heating Engineers Hold Annual Meeting

On Jan. 20, 21 and 22 the American Society of Heating and Ventilating Engineers held its annual meeting in the Engineering Societies Building, New York City. A number of interesting papers were presented and there was a large attendance to take part in their discussion.

On Tuesday the first session was called to order at 2 p.m. by President Hale. Routine business, committee reports and reports from the chapters occupied the time. The report of the committee on testing house-heating boilers, which was presented at Buffalo last July, had been printed and was read. It included instructions on apparatus and instruments, rules for conducting evaporative tests, suggestions for starting and stopping and a formula by which to rate a boiler. Written discussion on the report was requested, and a committee was appointed to confer with manufacturers, architects and the National Association of Master Steam and Hot-Water Fitters for the purpose of drawing up standard specifications for this type of boiler.

On Tuesday evening, E. Vernon Hill gave a report of the work of the ventilation division of the Chicago health department. The model ventilation law, got up by the committee on compulsory legislation, created extended discussion which was carried over until Wednesday morning, and was finally disposed of by appointing a committee to consider the objections offered. This committee, reporting Thursday afternoon, suggested a careful revision of the report and specified some of the more important requirements for the guidance of the committee having the matter in hand. A motion-picture lecture on the manufacture of steel pipe from the mining of the ore to the finished product was the feature of this session.

Wednesday afternoon the tellers of election reported the following officers for 1914: President, S. R. Lewis, Chicago; first vice-president, E. F. Capron, Chicago; second vice-president, D. D. Kimball, New York; treasurer, J. A. Donnelly, New York; directors, John F. Hale, Camden; W. W. Macon, New York; John R. Allen, Ann Arbor; F. T. Chapman, New York; J. M. Stannard, Chicago; Frank G. McCann, New York; F. I. Cooper, Boston and H. M. Hart, Chicago.

The first papers of the meeting were those of A. M. Feldman. One on "A Ward-cooling Plant in a Hospital" described an experimental installation at the Mt. Sinai Hospital in New York City. Outdoor air is forced by a motor-driven fan through a water chamber in which the water is cooled by brine coils. From this chamber the air is forced through an upper chamber containing additional brine coils and thence through short ducts into two small wards, where the cooled air enters near the floor level. The average temperature in the wards for 42 days was 69 deg. F., when the outside temperature averaged close to 80 deg. On one occasion the ward temperature reached 74 deg., but at this time the temperature of the street rose to 93 deg. Humidity readings taken on 25 different days averaged 60 per cent.

The second paper described the equipment for "Cooling Two Rooms in a Country Residence." An insulated box provided with two brine tanks containing ammonia coils was placed in the attic. The top of the box was connected with a short duct to the roof dormer for taking in fresh air, and from the ends near the bottom two galvanized-iron ducts were connected to the ceiling registers of the two rooms. Fresh air enters the top of the box, is cooled, and then drops by gravity through the registers to the floors of the rooms. It escapes through partially opened windows. A motor-driven 5-ton ammonia compressor is part of the equipment, which maintains a temperature 6 deg. lower than out of doors. A number of committee reports followed, the first being on standardization of the use of the pitot tube. The

committee outlined a practical method, explaining how to make a pipe traverse and giving constants by which to multiply the velocity pressure taken at the center for approximate results. For pressure readings of one inch or less the use of an Ellison Differential draft gage graduated to hundredths was recommended, and for pressures over one inch an Ellison gage or a U-tube graduated to tenths.

"Heating Practice in Sweden," by H. T. Theorell, was the next paper. The author gave the status of the art in his country, outlining the relations between the manufacturer, the contractor and the engineer and the comparative use of hot air, water and steam. Broadly, Swedish practice has developed along the same lines as in Germany.

An interesting paper by H. W. E. Muellenbach, telling what the Germans are doing in the heating line, and another on French practice by Gustave Devesson, were read on Thursday. These three papers will be given attention in later issues.

Prof. John R. Allen's paper on "Coefficient of Heat Transmission in a Pressed Steel Radiator" was read by W. F. Verner. From comparative tests of cast-iron and sheet-steel radiators it was shown that the coefficients of heat transmission were approximately the same, and that the relative speeds of heating up a room were not appreciably different, although the condensation for the first 20 min. was considerably more in the cast-iron radiator, the excess being caused by the greater weight of metal. The paper would have been more instructive if steam had been taken from a limited supply such as a boiler which will supply but little more than the heat loss from the room or building in zero weather. This is the condition found in practice, and in such a case the time element would have been in favor of the pressed-steel radiator.

More committee reports, and in particular one by D. D. Kimball on the work and the equipment of the New York State Ventilation Commission which has been provided a fund of $50,000, ended the session.

On Thursday morning C. M. Ripley read his paper on "Life of Building Power Plants," in which he cited a number of plants in New York City, which have been in service from 15 to 31 years. Basing depreciation on the life of the plant, the summary of the paper showed an average of about 4 per cent., and in one case it was only 1½. R. P. Bolton objected to this method of rating depreciation. It is not a question of how long a machine will run, for it loses its value just as soon as some other machine of greater efficiency is on the market. A certain firm out West had scrapped machines only 5 years old. It is possible to find plenty of old engines, but the space they occupy and the cost of running does not compare favorably with present-day equipment or with the cost of current purchased outside. For commercial depreciation, a life of 20 years is too long; 15 years is more nearly right, and in some cases less. Other discussion, foreign to the subject, followed, in which Mr. Bolton showed his interest in the central station, while Mr. Ripley naturally favored the isolated plant.

Another paper by John R. Allen on the "Effect of Time in Determining Radiation" was next read. The author considered four principal factors: The heat required to warm the interior structure such as windows, walls, floors and furnishings; that to warm the air in the room, and that to take care of the losses through the walls and windows, which included diffusion and floor and ceiling losses. In the paper, mathematical expressions were developed for these factors and curves were included showing the length of time required to heat a building of certain dimensions and construction with varying amounts of radiation. In the discussion it was pointed out that humidity, the effect of the wind and of the sun's rays had been neglected by the author. The contents of some buildings also have a decided effect on the time of heating up, and so has the apparatus itself when supplied with the limited amount of steam common in practice. Window leakage, depending on the construction, also affects the time element.

"Flow of Steam in Pipes," a paper doing credit to the author, H. W. Verner, was then presented in abstract. Fundamental principles relative to steam led up to a consideration of the fundamental equations of various authorities on the subject. These equations were put into suitable form for the plotting of logarithmic charts appearing in the paper. Pressures between atmospheric and three pounds were considered. The charts dealt with sizes of pipe from ⅜ to 15 in. in diameter, and much of the data on B.t.u. capacity of pipes and pressure drop were given in tabular form.

Thursday afternoon was devoted to the paper on "Heating Practice in Germany" previously mentioned, topical discussions on the fractional valve and experience in heating concrete construction. When radiation proved insufficient in concrete buildings, it was too often the custom to install more heating surface instead of spending money on window treatment and the provision of a false ceiling to prevent excessive radiation from the roof. For steam systems, down feed was advised and the provision of doors to cut off the suction inside the building was worthy of attention. Changes in the constitution, the installation of the newly elected officers and other matters of business brought the last session to a close.

Sightseeing trips about the city had been arranged to entertain the ladies, and the feature for all was the banquet held on Wednesday evening in the Hotel Martinique. Nearly 200 were in attendance and they listened with interest to John F. Hale, toastmaster, and a number of other speakers.

Marine Engineers' Washington Convention

The National Marine Engineers' Beneficial Association of the United States of America convened in its thirty-ninth annual session at 10 a.m., Jan. 19, at the Raleigh Hotel with the following officers: Wiliam F. Yates, national president; George H. Bowen, second national vice-president; Charles N. Voxburgh, third national vice-president; George A. Grubb, national secretary; Albert L. Jones, national treasurer. The following were appointed as the committee on credentials: Thomas C. Moore, E. C. Mausshardt, E. E. Morris, E. M. Roberts, James W. Hare.

At 11:30 a.m., National President Yates introduced Rear Admiral Griffin, Engineer-in-Chief of the U. S. Navy, who addressed the members. Captain Charles A. McAllister, Engineer-in-Chief of the U. S. R. C. S., followed in a humorous vein and advised regarding the status of the engineering profession. Honorary membership was conferred upon Rear Admiral Robert Griffin.

The convention was opened by National President Yates. The privilege of addressing the convention was accorded Andrew Furuseth, president of the International Seamen's Union, and Mr. Ross, president of the National Marine League. A recess was then taken until 5 o'clock.

The reports of the vice-president, the secretary and the treasurer were read and approved. Invitations were extended to hold the 1915 convention in San Francisco, Atlantic City, New York, Chicago, Wilmington, Galveston, and Los Angeles. At 5:18 p.m., adjournment was taken.

At 10 a.m., Jan. 20, Andrew Furuseth was introduced and presented a resolution which was referred to the committee on legislation.

President Yates then read his decisions given to the various associations during the past year. He appointed Representatives Jones, Kelly and Yates, as a committee to wait on Assistant Secretary Sweet regarding revision of the inspection service. The meeting then adjourned until 2 p.m.

At the afternoon session President Yates read correspondence of importance regarding high steam on government boats from Chief Engineer W. B. Ladue.

At the third session, Jan. 21, President Yates introduced Mr. Ross, president of the National Marine League. His address was referred to the committee on the good of the order.

At the afternoon session the following officers for the year 1914 were elected: National president, William F. Yates; first national vice-president, E. C. Mausshardt; second national vice-president, George H. Bowen; third national vice-president, Charles N. Vosburgh; national secretary, George A. Grubb; national treasurer, Albert L. Jones. Advisory board, Representatives Delahunty, Brown and Goelet. Trustee, Representative Crum.

The entertainment features were thoroughly enjoyed. These were a theater party on Monday night for everybody and one exclusively for the ladies on Wednesday night, and autos took several sightseeing parties about the city. Of course, the smoker tendered the engineers by the Supply Men's Association was the main event, and was heartily enjoyed by all. Among the guests were prominent Arm and Navy officers. As for entertainers the New York "Bunch" and others equally well known kept things moving throughout the evening.

The fortieth convention will meet in Washington, D. C., the week beginning Jan. 18, 1915.

Peculiar Traffic Delay—The high wind was the cause of the coldness and slowness of the cars on the elevated, subway and surface lines in New York City during the rush hours, Tuesday evening, Jan. 13. Coming at low tide, it so much further lowered the water in the East River that the intake pipes to the condensers in the Waterside station were marooned. This made it necessary to so far reduce the power output that the cars had to turn off their electric heaters to save power and run at about half speed. It was two hours before both full speed and heat could be restored.

NEW PUBLICATIONS

FOWLER'S MECHANIC'S AND MACHINIST'S BOOK AND DIARY, sixth annual edition; by William H. Fowler. Published by the Scientific Publishing Co., Manchester, Eng. Size 3⅜x6 in.; 476 pages. Paper. Price, sixpence.

The sixth annual edition of this book, intended as a synopsis of rules for mechanics generally, is now available. Some data have been added.

FOWLER'S MECHANICAL ENGINEER'S POCKETBOOK. By William H. Fowler; sixteenth annual edition. Published by the Scientific Publishing Co., Manchester, Eng. Size 3⅜x6 in.; 576 pages. Cloth, 1s. 6d.; leather, 2s. 6d.

The sixteenth annual edition of this English mechanical engineer's pocketbook is about the same as other editions, with a little additional data compiled to bring the volume uptodate.

ARITHMETIC OF THE STEAM BOILER. By Charles J. Mason; published by the McGraw-Hill Book Co., New York. Cloth. Size, 4½x6¾ in., 219 pages. Price, $1.

This volume is the latest addition to the "Power Handbooks." It is esentially a reference book showing various applications of arithmetic to steam boilers, particularly to calculations of the strength and efficiencies of joints. The book does not aim to teach the elements of arithmetic.

The volume is in three parts, the first dealing with calculations involving the strength of miscellaneous seams, the size of feed pipes, chimnies, etc. The third contains abstracts of the rules of the United States Board of Supervising Inspectors of Steam Vessels and of the Massachusetts Boiler Rules. Many useful tables are given in this part.

The book should be well received by power-plant engineers.

THE FITTING AND ERECTING OF ENGINES. By C. Leslie Brown. Published by Elmot & Co., Limited, 65 King Street, Manchester, Eng. Cloth; 153 pages, 5¼x8½ in.; 114 illustrations. Price 3/6 net (87c.).

This book, a compilation from a series of articles that appeared originally in the "Mechanical World," is written in plain shop language for the express purpose of instructing and assisting young or inexperienced fitters and erectors in practical work both in the shop and in the field.

The author starts with a comparison of modern shop practice with that which obtained only a few years ago, after which he follows the course of a modern high-speed engine in detail from the foundry and forge shop through the processes of fitting and erecting on the shop floor.

In its 23 chapters the book covers the field indicated in the title, and while much of the matter is in the nature of editorial observation, no words are wasted on irrelevant subjects.

Alignment, the scraping and adjusting of bearings, metallic packing, forced lubrication, high-speed and Corliss engine valve setting, the care and handling of machine parts and rigging and the general behavior of the workman both in the shop and field are among the many subjects treated.

The work is English and tells of English practice in English shops, but it is well worth the careful study of any mechanic engaged in fitting and assembling engine parts in the shop or erecting the complete machine where it is to run, or of foremen in charge of such work.

HEATING SYSTEMS AND THE DESIGN OF HOT WATER AND STEAM HEATING APPARATUS. By F. W. Raynes. Published by Longmans, Green & Co., London and New York City. Cloth; 328 pages, 5½x8¾ in.; 158 illustrations, tables. Price, $3.50.

As indicated in the title, the book takes up both steam and hot-water heating. Under the latter heading, gravity and forced circulation are covered, and under the former both low-pressure live-steam and vacuum systems of heating are given attention. Heating surfaces, heat loss from buildings and the sizing of pipes are naturally included and the last two chapters of the book are devoted to boilers and the temperature control of buildings.

With some revision, the book would be excellent for student use. The chapters on vacuum steam heating are original and give thoroughly the limitations of such systems. The diagrams of different systems of piping are clear, and the method of illustration is to be commended. To the steam end of the book there can be no serious objection, unless possibly to the charts showing the flow of steam in pipes. In some of these charts one division has been made equal to 2,000,000 B.t.u. per hr., or about 60 boiler-horsepower. Accuracy would call for a chart on a larger scale.

The chapters on hot-water heating, and especially those relating to forced circulation, are seriously at fault, and will require considerable revision to bring them up to a standard comparable with the balance of the book. Much of the subject matter is incorrect, or at least misleading, and there is objection to the formulas used.

In stating the respective merits of steam and forced hot water for district heating, the author asserts that steam is more advantageous for industrial centers due to its possible use for manufacturing purposes. It is bad practice to utilize the distribution mains of any heating system, whether steam or water, to convey heat for manufacturing purposes, as the heating plant is inoperative in summer, and the mains are then too large and consequently inefficient for the other service. Such a system should be operated on its own mains properly proportioned for the work.

The author lays great stress on the cost of pumpage in forced hot-water heating. This depends on the size of the installation. If the exhaust steam from the pump is utilized, all the heat will be returned to the system, but the operation will be live steam to that extent. In a properly designed system the cost of pumpage should be less than in most vacuum steam systems. The reader is advised that fittings of the O. S. type should be used sparingly in gravity circulation due to the resistance introduced, but that on forced circulation there is less objection to their use. It is difficult to see how these statements can be reconciled as the same objection should hold with greater emphasis for forced circulation.

Except in the case where the heating load exceeds the amount of exhaust steam available, the chapter on forced circulation dealing with the use of exhaust steam from condensing engines and turbines is impractical. With the arrangement shown by the author, the vacuum would be variable and not much more than sufficient to relieve the engine of pressure above atmospheric. This condition would be fatal to the economical operation of a steam turbine. The illustration showing a hot-water system for high buildings is practically identical with the cut which appeared in "Power," Dec. 19, 1911, with the exception that the condensing feature is eliminated. This removes the advantage of hot-water heating in this class of work as the engine load the greater part of the time requires steam in excess of that necessary for heating. Unless vacuum were carried, reducing the steam rate on the engine, there would be no reduction in the total fuel due to a more economical heating system.

In another illustration a condenser is shown, but the arrangement would be impractical with several machines, some operating at full vacuum and others under partial vacuum on the heating. If all machines were operated on reduced vacuum for the heating, the economy of the plant would be considerably lessened.

The suggestion on operating a live-steam heater in conjunction with an exhaust heater is bad practice, as one may operate to cool the water heated by the other. When the live-steam heater is used the engines should be exhausting at atmospheric or back pressure. The method of regulating the output of the heater by submerging the tubes in the condensation is all right for the live-steam heater but unnecessary in an exhaust heater.

The hydraulic formulas for the capacity of pipes for both gravity and forced circulation do not check with those of the best authorities. The discharge for a 3-in. pipe under a head corresponding to a velocity of 10-ft. per sec., should be 1900 lb. per min. The author's formula gives 1500 lb., which is more than 20 per cent. less. For each size of pipe the same factor is used for all velocities, which, when reduced to the same basis, is very different from any given by Fanning for the usual velocities.

In the charts giving the capacities of pipes for hot-water heating, only pipes up to 4 in. in diameter are included. As forced circulation is necessarily used on plants of large capacity in which the mains are seldom as small as 4 in., the charts are of little use. To be of practical value, they should be extended to include pipes up to 12 in. in diameter. The use of hydraulic gradients as abscissas is of no particular advantage, as computation of the loss in head is required for each reading.

In describing shunt circuits, the author states that the flow through the shunt will be inversely proportional to the resistances in the branch and main within the shunt. The resistances, between the points of joining, of the shunt and of the main are precisely the same, and this is true of the loss of head in each circuit. According to the author's statement there would be equal flow, which, of course, is not true. The velocity, diameters and lengths are such as to make the losses in head the same between the two points in question.

It is apparent that the author is not familiar with hot-water heating, and has failed to keep pace with the advance made during the last few years in this country. It is only fair to state, however, that, with one or two exceptions, there is no book which adequately treats this branch of the heating art. It is not surprising, then, that the present book is also lacking in this respect.

The author and title catalog for 1914 of the Public Service Corporation of New Jersey has been published. This preliminary list will be followed by a classified catalog. The library has proved its wide usefulness to its patrons and brought a broad range of books and other publications within their reach. Mrs. Helen I. Brewster is the librarian.

BOOKS RECEIVED

ENGINE-ROOM CHEMISTRY. By August H. Gill. McGraw-Hill Book Co., New York. Second edition; cloth; 211 pages, 4½x7 in.; illustrated; tables. Price, $1.

INVESTIGATING AN INDUSTRY. By William Kent. John Wiley & Sons, Inc., New York. Cloth; 126 pages, 5x7½ in. Price, $1.

HANDBOOK OF ELECTRICAL METHODS. Compiled from the Electrical World. Published by McGraw-Hill Book Co., New York. Cloth; 285 pages, 6x9¼ in.; illustrated. Price, $3.

FOWLER'S MECHANICS' AND MACHINISTS' POCKET BOOK AND DIARY FOR 1914. By Wm. H. Fowler. Scientific Publishing Co., Manchester, England. Paper; 476 pages, 3¾x6 in.; illustrated; tables. Price sixpence.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK FOR 1914. By Wm. H. Fowler. Scientific Publishing Co., Manchester, England. Cloth; 576 pages, 4x6 in.; illustrated; tables. Price 1s. 6d.

THE "MECHANICAL WORLD" POCKET DIARY AND YEAR BOOK FOR 1914. Emmott & Co., Manchester, England. Cloth; 443 pages, 4x6¼ in.; illustrated; tables. Price 25 cents.

THE "MECHANICAL WORLD" ELECTRICAL POCKET BOOK FOR 1914. Emmott & Co., Manchester, England. Cloth; 4x6¼ in.; illustrated; tables. Price, 25 cents.

Civil-Service Opportunities

COMPETITIVE EXAMINATIONS *for the civil-service positions named below will be held on the dates given. Applications and further information may be had by addressing the respective commissions. Candidates must be citizens of the United States and residents of the cities in question, and at least 21 years of age, unless otherwise specified.*

Situation for Pumpman—The Philadelphia Civil Service Commission will hold an examination, Feb. 11, for the position of pumpman in the electrical bureau, department of public works. Salary, $3 a day. Address the Civil Service Commission, room 875, City Hall.

Situation for Draw-Bridge Operator—The Philadelphia Civil Service Commission will hold an examination, Feb. 13, for steam draw-bridge operator, a position in the Bureau of Highways, Department of Public Works. Salary, $1000. Address the Civil Service Commission, room 875, City Hall.

SOCIETY NOTES

Francis S. Peabody, president of the Peabody Coal Co., Chicago, Ill., recently gave a lecture before the College of Engineering of the University of Illinois on "The Mining and Utilization of Illinois Coal." The lecture was illustrated with the first successful motion pictures taken underground, and they gave a vivid idea of the actual conditions met in coal mining.

The Pittsburgh chapter of the National Association of Stationary Engineers held its first winter educational meeting Jan. 12, at which R. B. Ambrose, of the Carnegie Institute presided. H. A. Hoffman, of the General Electric Co., read a paper on "Steam-Flow Meters," which was followed by a general discussion of the device used to measure steam in its different uses.

On Saturday evening, Jan. 17, the Engineers' Blueroom Club held its annual ladies' night and installation of officers at the New American House, Boston, Mass. Over 250 attended. Following the dinner, there was a most enjoyable cabaret show and an informal dance was given in the old Colonial dining room. The officers for 1914 are, President, Peter H. Bullock, chief engineer, Massachusetts Reformatory, Concord; vice-president, Merle W. Eastman, chief engineer of the Dorchester power station, Boston Electric Ry. Co.; secretary, Thomas A. Ray, chief engineer, Reece Building, Boston; treasurer, Thomas B. Constant, mechanical engineer, Johns-Manville Co.; sergeant-at-arms, Ernest E. Erickson, chief engineer, Harvard Medical School. The members of the executive committee are the president, vice-president, secretary, treasurer and John F. Cochran, Charles B. Klingman, Myles M. Erb, Ernest R. Stevens and Ernest A. Ford. The installing officers were Past President Herbert E. Stone and George W. Knowlton. On behalf of the club, Past President Stone presented Past President Campbell a gold and diamond jewel, and Messrs. Trudo, Allen and Klous bouquets of cut flowers for their good work on the entertainment committee. The club has a membership of 560.

PERSONALS

Otto Dieckmann, Jr., manager of the Kewanee Boiler Co., Twelfth and Olive Sts., St. Louis, Mo., was elected trustee in bankruptcy for the Kauffman Heating & Engineering Co., 2109 Olive St.

Harry B. Allen, formerly with the Ashton Valve Co., has become affiliated with Thomas Foster & Co., factory representatives, 900 Michigan Ave., Chicago, Ill., in the capacity of vice-president and treasurer.

S. Rosenzweig, until recently mechanical engineer with the Erie City Iron Works, Erie, Penn., has joined the York Manufacturing Co., with whom he will act in the capacity of consulting engineer in the steam-engine department.

Prof. J. M. Bryant, of the department of electrical engineering of the University of Illinois, has recently been employed by three cities of Illinois, Jacksonville, Kewanee and Lewistown, as consulting engineer in connection with municipal electric-lighting work involving both technical and economic problems.

OBITUARY

EDWIN EMERSON NOLAN

Edwin Emerson Nolan, head of the materials disposition department of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Penn., died at his home 517 Center St., Wilkinsburg, Penn., on Tuesday, Jan. 13. He was born in Chicago, Aug. 10, 1857.

Mr. Nolan began work with the Westinghouse Electric Co. in 1887 just about the time it began operations on Garrison Alley in the city of Pittsburgh. He was subsequently made superintendent of the Allegheny factory of the company and as such had charge of building the first alternating-current generators for the Niagara plant. He retained this position until the factory was converted into a foundry.

In 1898 Mr. Nolan was sent to France to establish a factory at Havre, where he remained until 1902. After his return to the United States, and on account of his familiarity with Westinghouse apparatus, he was placed in charge of the materials disposition department, which position he held until his death.

Mr. Nolan was a mechanical engineer and an inventor of considerable ability; one of his inventions is now in use on street railway motors

He was noted for his thoroughness in all undertakings, and was an exceedingly reliable and conscientious employee. His kindly disposition and method of dealing with men endeared him to a large number of acquaintances which he had made in this country and in many foreign countries.

Mr. Nolan leaves a widow and two sons and two daughters.

A Red Light Signal for the Hoisting Engineer is provided at the Kennedy mine on the north Cuyuna range, to serve as a memory help. A red electric bulb is placed in front of the engineer's stand in line with the center of the drum. At the end of a trip the reverse lever is supposed to be always thrown over. This operation flashes the red bulb and thus impresses itself on the engineer's memory. It is well known that overwinding accidents are often caused by the fact that the engineer thinks he has thrown his reverse for the next trip, when, in fact, he has not, so that on starting he pulls the conveyance at the shaft collar up into the sheave. The use of a simple device like this ought to help to prevent such accidents.

Concrete Resisters for lightning-arrester service, as used by a Georgia power concern, are made of concrete blocks 4 ft. long and 1 sq.ft. in cross-section, set upright at the point of installation. Two squares of bronze or copper mesh cast into the blocks near either end connect with the source of energy and with a ground wire.